U. S. FEDERAL FISHERY RESEARCH ON THE GREAT LAKES THROUGH 1956

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EXPLANATORY NOTE

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By

Ralph Hile
Fishery Research Biologist
Bureau of Commercial Fisheries

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ABSTRACT

The present article is a revision and expansion of my earlier paper: 25 years of Federal Fishery Research on the Great Lakes. Spec. Sci. Rep.: Fish. No. 85, 1952. Two circumstances made a revision desirable at this time. First, publications since 1952 have added greatly to the literature based on Federal studies on the Great Lakes. Second, the Great Lakes Fishery Commission, established by treaty with Canada, was organized in Ottowa in April 1956 and held its first annual meeting in Ann Arbor in November 1956. The entry of the Commission on the scene marks the start of an era of further expansion and heightens interest in past activities.

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INTRODUCTION

The major purpose of this publication is to present an annotated bibliography of papers resulting from Federal investigations on the Great Lakes fish and fisheries since the formal initiation of a continuing research program by the Fish and Wildlife Service.[1/] It is believed that this purpose can be served best by prefacing that bibliography with a brief account of the origins of Great Lakes Fishery Investigations and of the circumstances that have guided their course.

Great Lakes Fishery Investigations, with John Van Oosten as the first Chief, was established in 1927. This establishment did not mark the actual beginning of modern research on the Great Lakes fisheries, for Walter N. Koelz (who resigned in 1927) had been on the staff of the Division of Scientific Inquiry (now the Branch of Fishery Biology) since 1918 and Van Oosten since 1920. The term, "program", can hardly be applied to the early investigations that started in 1918. Actually, the Federal contribution amounted to little more than grants-in-aid to the personal and largely independent researches of Koelz on the taxonomy of Great Lakes coregonids and of Van Oosten on the life histories of the lake herring and whitefish. The work of this period led nevertheless to three monumental contributions to fishery literature--Koelz' (1929) monograph on the coregonids of the Great Lakes and Van Oosten's papers on the scales of whitefish of known age (1923) and on the life history of the lake herring of Lake Huron (1929).

Born in the crisis arising from the disappearance of the Lake Erie cisco, Great Lakes Fishery Investigations has forever since experienced the varying fortunes that inevitably befall an organization whose very life depends on the existence of emergencies that cry for attention.[2/] Seldom has money been adequate to the task assigned; commonly it was supplemented by funds from State and private agencies interested in particular problems; never until most recently could long-term researches be set up that would contribute to a fundamental understanding of the fish populations and of the factors that control their level of productivity.

Thus the history of Federal researches on the Great Lakes has been one of loosely related projects. Only a glance at the record of funds is needed (table 1) to understand how futile it would have been to attempt continuing observations on even a small segment of these extensive and scattered fisheries. Yet for all the discontinuity and lack of a sustained central program, Great Lakes Fishery Investigations has not been ineffective. Not only were satisfactory solutions found to the several practical problems that attracted outside support to the individual projects in earlier years; in addition, staff members have published many and varied reports which, as an examination of the bibliography given later in this article will prove, have made available a large store of information on the Great Lakes fisheries. These past studies have provided much of the foundation for an effective inquiry into the factors that control the productivity of the Great Lakes.

THE GREAT LAKES RESEARCH PROGRAM, 1927-1956

The research program of the Fish and Wildlife Service on the Great Lakes divides itself conveniently into three distinct periods: the early years, 1927-32, of intensive field work on a variety of projects; an intermediate period, 1933-47, of stringently reduced budgets; and the present era in which primary concerns are research on methods for the control of the sea

1/ To avoid confusion the title Fish and Wildlife Service will be employed throughout this discussion even though the joining of the Bureau of Fisheries and the Bureau of Biological Survey to form the Service did not take place until 1940.

2/ Annual reviews of the activities of Great Lakes Fishery investigations may be found in: Progress in biological inquiries by Elmer Higgins. Reports of the U. S. Commissioner of Fisheries for 1927-1939.

Table 1.--Allotments of funds to Great Lakes Fishery Investigations, fiscal years 1928-1957

Fiscal year	Salaries, permanent employees	Expenses	Total
1928	$ 6,180	$ 9,000	$ 15,180
1929	7,340	13,656	20,996
1930	7,500	10,890	18,390
1931	8,725	15,000	23,725
1932	11,140	15,280	26,420
1933	12,000	2,950	14,950
1934	10,460	550	11,010
1935	12,357	1,235	13,592
1936	12,840	1,585	14,425
1937	11,050	1,500	12,550
1938	12,300	1,500	13,800
1939	14,269	1,650	15,919
1940	14,340	2,379	16,719
1941	16,340	1/ 7,010	1/ 23,350
1942	13,440	1/ 5,310	1/ 18,750
1943	12,520	1,350	13,870
1944	12,240	2,100	14,340
1945	15,190	1,300	16,490
1946	14,435	850	15,285
1947	19,798	1,000	20,798
1948	20,508	18,358	38,866
1949	26,561	5,020	31,581
1950	61,425	225,129	286,554
1951	129,047	73,096	202,143
1952	152,414	187,597	340,011
1953	178,010	212,375	391,385
1954	164,481	202,764	367,245
1955	171,100	172,222	343,322
1956	185,995	167,238	353,233
2/ 1957 C	173,000	397,000	570,000
S	93,000	50,000	143,000

1/ Expense allotments for 1941 and 1942 include funds allocated to defray costs of activities of U. S. members of the International Board of Inquiry for the Great Lakes Fisheries. Actual allotments to Great Lakes Fishery Investigations were $1,430 in 1941 and $1,515 in 1942; totals for the 2 years were $17,770 and $14,955.

2/ C, By contract with Great Lakes Fishery Commission, S, Service allotment.

lamprey and the implementation of a central program. The transition from the first to the second period was as abrupt as it was fatal to all plans for sustained observations on the fisheries. The change to the third period was more gradual in that some special funds were available for the study of the sea lamprey in fiscal years 1948 and 1949, although budgets adequate for effective research on that parasite first came near the middle of fiscal year 1950.

Years of Extensive Field Work, 1927-32

The troublesome situation in Lake Erie that brought about the establishment of Great Lakes Fishery Investigations was also the first to receive the attention of the newly organized staff. Most of the problems existing then were of long standing. For years the industry on Lake Erie had been suffering decreasing returns in the face of increasing fishing pressure; for years operators of gill nets and trap nets, the two principal types of gear, literally had been at one another's throats, each group accusing the other of viciously destructive fishing practices and joining their voices only in a common denunciation of pollution as a major cause of the decline in the abundance of fish. Urgently as these matters needed attention, it still required the complete collapse (in 1925 and subsequent years) of the lake's most productive fishery, that for the cisco, to stimulate action for a comprehensive research project.

The Lake Erie project was started in 1927, carried on intensively in 1928 and 1929, and continued on a reduced scale through the spring of 1931. This undertaking was a cooperative venture toward which the following organizations contributed facilities, funds, and personnel: U. S. Fish and Wildlife Service; U. S. Coast and Geodetic Survey; Ohio Division of Conservation; New York Conservation Department; Ontario Game and Fisheries Department; Health Department; City of Buffalo; Buffalo Society of Natural Sciences. Through the collaboration of these several agencies a concerted attack was possible on such problems as factors of abundance and distribution of fish, regulation and management of fisheries, and pollution in relation to fisheries and municipal water supplies.

Although the Service made a limnological survey of eastern Lake Erie possible by supplying the services of the research vessel Shearwater, members of the Great Lakes staff did not participate actively in the scientific activities of that survey. Rather, the Great Lakes staff concentrated on limnological studies directed toward an appraisal of the effects of pollution in the western end of Lake Erie and on studies of "savings gear", the first investigations of this type known to have been carried out in North America. The "hybrid" trap net designed to reduce the capture and handling of undersized fish which was recommended as a result of these studies has long since become a standard gear. In fact, many fishermen who at first opposed the recommendations as radical and impractical later voluntarily exceeded the original specifications in providing for the release of small fish. During the course of the field operations, staff members seized upon the occasion to amass large amounts of biological materials and data that were later to form the basis for a number of publications. These materials served also as the principal basis for doctoral dissertations at the University of Michigan by Deason on the morphometry and growth of pikeperches, and by Jobes on the growth of yellow perch. Nor has the store even yet been fully exhausted.

All of the several field projects carried out in the late 1920's and early 1930's were similar to the Lake Erie investigations in that: they were initiated to obtain information on immediately pressing problems; support from other agencies through allocation of funds, assignments of personnel, or supply of equipment made them possible or permitted operation on a far more effective scale than the relatively modest Service budget would have allowed; they provided the opportunity for the collection of biological materials and data. Brief comments on these projects are given in the following paragraphs.

The experimental studies on pound-net meshes in Saginaw Bay (1928-30), requested and supported by the State of Michigan, were carried out in an attempt to determine a single mesh size that might prove suitable for all impounding nets in that region and in other waters with similar fishing conditions. Previously, three minimum legal mesh sizes had been stipulated according to the species of fish. Inasmuch

as a variety of species was ordinarily taken together, these regulations obviously were burdensome and almost unenforceable. The recommendation resulting from the experiments for a single maximum mesh size to replace a series of minimum mesh sizes led to the solution of this vexing problem not only in Saginaw Bay but in numerous other fishing areas in which the catch is made up of a variety of species.

Least pretentious of the early field projects was the survey of Lake Champlain made in 1930-31 in cooperation with the Canadian Government to ascertain the effects of commercial fishing in the Canadian waters of Missisquoi Bay on the abundance of walleyes in United States waters. The periods of field work were limited in both years, and the studies did not lead either to formal recommendations or a completed report.

The experimental chub-net investigations carried out in Lake Michigan in 1930-32 from the research vessel Fulmar were designed to provide information on regulations, particularly on mesh size, that would permit the most efficient exploitation of the stocks of chubs (deep-water ciscoes) with the minimum destruction of small lake trout that are regularly taken in chub gill nets. The States of Michigan and Wisconsin and four net manufacturers gave liberal financial support to this operation. Although the project proved disappointing in that both of the supporting States ignored the recommendations resulting from the work, the materials and data collected formed the basis for a number of valuable papers and still constitute a major source of information on the growth, distribution, and abundance of fishes in the deeper waters and on the bottom fauna, plankton, and hydrography of the lake.

The 1931-32 survey of the deep-trap-net fishery in Lakes Huron and Michigan was conducted in cooperation with the State of Michigan (which carried the bulk of the cost of field operations) to obtain information on which to base regulation of a new and phenomenally efficient net that early threatened ruin to the whitefish fishery in those areas in which the gear was fished intensively. Although detailed observations on the fishing action of the deep trap net and extensive data on seasonal abundance and movements of whitefish and other species permitted specific recommendations on regulations shortly after completion of the survey, legislative action was delayed until the whitefish fishery had collapsed in all major production centers of Lake Huron.

During this period of active field work four scientists were added to the full-time staff of Great Lakes Fishery Investigations--Hilary J.. Deason in 1927, Stillman Wright (by transfer from Interior Lakes Investigations) in 1928, Frank W. Jobes in 1930, and Harry A. Hanson (by transfer from North Atlantic Fishery Investigations) in 1931. Hanson was transferred to Washington headquarters in less than 2 years and Wright left in 1933 to accept a position with the Brazilian Government. Deason continued on the staff until 1940 when he was transferred to Washington. Except for a 2-year period in 1935-37 at Washington headquarters and with Columbia River Salmon Investigations, Jobes remained in Ann Arbor until 1949 when he resigned to enter teaching.

Period of Reduced Budgets, 1933-47

The depression of the 1930's brought drastic curtailment of governmental research activities and pressure for reduction of personnel. Field work on all major projects ended in order to retain as many as possible of the staff in anticipation of better times. Through reorganization and adjustment elsewhere Ralph Hile, still a member of the staff, was transferred to Great Lakes Fishery Investigations from his work on northern Wisconsin lakes for the purpose of developing procedures for the analysis of the statistics of the commercial fisheries of the Great Lakes. Hile's biological studies, however, continued for nearly 10 years to be based principally on materials and data from the interior lakes of Wisconsin, waters peculiarly well suited to research on certain types of ecological problems, the results of which could be useful in the conduct of studies on the Great Lakes. This Wisconsin work was accordingly considered an integral part of Great Lakes Fishery Investigations.

The period of scanty budgets that started in 1933 continued through fiscal year 1947. The figures of $7,010 for fiscal year 1941 and $5,310

for fiscal year 1942 recorded in table 1 do not represent relief to the poverty of Great Lakes Fishery Investigations since as is explained in the footnote to the table the greater part of the funds was required to cover the costs of the activities of the United States members of the International Board of Inquiry for the Great Lakes Fisheries. Thus Great Lakes Fishery Investigations passed through a 15-year period during which the amount available annually to meet all operating expenses--travel, subsistence, communications, supplies, equipment, wages of temporary employees, ...--consistently was less than $3,000 and in 2 years dropped below $1,000. Field operations of any consequence were out of the question. The only projects worth listing were the 1937-38 survey of the fisheries of the Potagannissing Bay, Lake Huron, supported by the Michigan Department of Conservation, and the 1938 survey of the fisheries of the Red Lakes, Minnesota, carried out in cooperation with the Office of Indian Affairs. Otherwise, field work was limited to "spot-checks" of problem situations or brief excursions to obtain materials needed to fill gaps in studies based on collections of the 1927-32 period.

This 1933-47 period was nevertheless one in which numerous significant publications were issued--and that despite the loss of Deason through transfer in 1940 and the nearly full-time occupation of the entire staff with the activities of the war-time agency, Office of the Coordinator of Fisheries, during 1942-45. Prevented by lack of funds from the continuation of past projects or the initiation of any new research, staff members devoted their time to the completion of reports based principally on the collections of the earlier years when greater allotments and especially the liberal support of outside agencies made field operations possible. Exceptional as the number of publications may have been in relation to size of staff and operational funds available, and valuable as they are as sources of information on the Great Lakes fish and fisheries, they do not reflect the type of research that the staff members would have desired and that has long been urgently needed on the Great Lakes. Even the original collections were handicapped by the impossibility of scheduling observations and sampling as a well-planned biological research program would require; rather, the collections had to be made as opportunity presented itself while major attention was given the "emergency" situation that had drawn outside assistance. Still more damaging was the lack of the continuity of observation that is so essential to an understanding of the changes that take place in populations. The effective use of the large body of information amassed during the first 20-odd years after the establishment of Great Lakes Fishery Investigations will depend on the continuity of subsequent researches.

Throughout much of this "intermediate" period of Great Lakes Fishery Investigations, Van Oosten, as Chief, devoted considerable attention to problems of fishery regulations. He attended many public and legislative hearings, prepared numerous memoranda on proposed or desirable legislation, and worked for interstate and international cooperation in the establishment of more restrictive and uniform regulations. At the same time he published a series of popular and semipopular articles in which he stressed: the progressive depletion of the major fisheries of the lakes; the need for immediate and drastic restrictions on fishing pressure to save the industry from collapse; the seeming futility, as indicated by past experiences, of attaining adequate and uniform regulations through voluntary cooperation of the lake states and Ontario; the desirability of a treaty with Canada for joint investigation and control of the Great Lakes fisheries. The publicity thus given to Great Lakes fishery problems was a major factor in the request of the Council of State Governments for the appointment of the International Board of Inquiry for the Great Lakes Fisheries (on which Van Oosten served as one of the United States members) and ultimately in the negotiation of a treaty between the United States and Canada for international investigation and control of the Great Lakes fisheries.[3/]

3/ Because of the strong opposition of one state and of much of the fishing industry, this treaty was never considered by the Foreign Relations Committee of the United States Senate. It was withdrawn from that Committee in 1955.

Sea Lampreys and the Expanded Great Lakes Fishery Investigations 1948-1956

Fiscal year 1948 saw the first Federal appropriation for the study of the sea lamprey, the predator that had reached the upper Great Lakes in the 1930's and by the late 1940's had eliminated the lake trout fishery in Lake Huron and had inflicted grievous injury in Lake Michigan. Both the Great Lakes staff and members of the industry had been aware of the threat for a number of years, but the emergency had not been sufficiently great to attract support for research on the problem. Most of the 1948 appropriation was consumed in the construction of the experimental weir in the Ocqueoc River and the 1949 allotment amounted to barely $5,000. Consequently, it was not possible in either year to carry out more than perfunctory research on the lamprey--appraisals of damage to the fishing industry, short-term surveys of streams to locate spawning runs, ... Serious experimentation on control methods was out of the question. Alfred Perlmutter, who had been transferred from North Atlantic Fishery Investigations in 1948 to head the sea lamprey studies, resigned in 1949.

The substantial allotment for fiscal year 1950 (which, because of delays of appropriation, did not become available until November 1949) made it possible for the first time to organize a comprehensive research program based entirely on Service funds. In consideration of the burden that the establishment and administration of a greatly expanded program would impose, Van Oosten was relieved of administrative duties to give full time to the completion of his numerous researches in progress and James W. Moffett was transferred from Central Valley Investigations to become the new Chief (January 1950).

Headquarters for the expanded Great Lakes Fishery Investigations continued to be in Ann Arbor, Mich. Field stations were established in 1950 at Hammond Bay (near Rogers City, Mich.), Marquette, Mich., and Sturgeon Bay, Wis., and in 1956 at Ludington, Mich. (The Sturgeon Bay station was closed in 1953 and its activities transferred to Ann Arbor.) The 60-foot research vessel Cisco (launched in 1951), specially designed for investigations on the Great Lakes has been considered as an independent "station". The Siscowet, a gill-net tug, remodelled for hydrographic work and for light trawling was purchased in 1952 and assigned to the Marquette station. The Musky, a trap-net boat purchased in 1951 has been employed in various studies in Green Bay, northern Lake Huron, and Saginaw Bay.

Although the allotments continued to be substantial in fiscal years 1951-1956 following the expansion of the investigations in 1950, this period was not a time of budgetary tranquility. In not one of of the 6 years was the final allotment as listed in table 1 included in the Fish and Wildlife Service budget as submitted to Congress. Annually, supplemental sums were added to the Department of the Interior budget in the U. S. Senate--in committee or from the floor; on occasion it seemed that the Investigations might be dismantled. In 1953, for example, the outlook for fiscal year 1954 was so poor that more than half the staff was placed under notice of "reduction in force" and the sea lamprey control operations on Lake Superior were discontinued in mid-season. Some staff members resigned because of the persistent uncertainties of employment.

It is believed that Great Lakes Fishery Investigations finally reached a dependable level of financial stability in fiscal year 1957 when funds for sea lamprey activities were obtained by contract with the Great Lakes Fishery Commission, established by treaty with Canada. It is anticipated that under this new international arrangement the lamprey program will receive the sustained and adequate support required for sensibly planned and orderly advancement. It is hoped also that fishery research may be supported more dependably through regular Service appropriations.

The Sea Lamprey Program

A division of the sea lamprey program into "research" and "control" activities is a matter of convenience and to a large degree artificial. All phases of the work--research on the lamprey to find vulnerable points in its life history, development and testing of control methods, and large-scale application of these

methods in the field--are in fact but parts of a single vast experiment in the reduction of a widespread and highly destructive population of parasites.

Research on the sea lamprey

At the time the sea lamprey program was expanded in 1950, the fundamentals of the natural history of that parasite had been made known through the graduate researches at the University of Michigan of Vernon C. Applegate, an employee of the Michigan Department of Conservation. Indeed, it was his broad experience and demonstrated competence in this field that led to his selection as Director of the Hammond Bay Fishery Laboratory. The newly established field station at once set about to continue and expand those portions of studies on which Applegate's findings were incomplete and to undertake new lines of investigation that previously had not been possible. Results of most of this work have been so well documented that only brief accounts of them need be made here.

Ecology of the sea lamprey.--Much additional information on the sea lamprey was obtained in the operation of various control devices where data were accumulated in such matters as: time and factors (temperature, water flow, ...) of migration of sea lampreys and associated migratory fish species: duration of runs; characteristics of sea lamprey spawning runs--length, weight, sex ratio in various periods of the run; kinds of streams utilized by lampreys. The inclined-screen-and-trap barrier in the Carp Lake River (tributary to the Straits of Mackinaw) has yielded data on sea lampreys recently transformed from the ammocete to the parasitic state--size, numbers produced annually, time and factors of downstream movement, length of larval life. The observations at barriers are being continued; particularly detailed records are maintained for tributaries chosen as "index" streams.

Movements of parasitic-phase lampreys tagged in the open lake indicated little or no homing tendency. Many of these lampreys were obtained for tagging in the course of experimental fishing operations carried out to study fish-lamprey relations in northern Lake Huron--abundance of lampreys and various species of fish, incidence of sea lamprey scars in relation to host species, size of fish, locality, and season.

A series of stream surveys designed to show the "lamprey potentials" of the various tributaries of the upper lakes has given a large amount of information on such points as: volume and rate of flow; temperatures and chemical characteristics of the water; natural and man-made barriers; extent of grounds suitable for lamprey spawning; extent of larval habitat. It is anticipated that these records will lead to a better understanding of the lamprey's selection of certain streams and its failure to spawn in others.

Laboratory studies of the development, growth, and feeding.--An early project at the Hammond Bay Laboratory was the rearing of parasitic-phase sea lamprey from the recently transformed stage to full sexual maturity. These experiments verified the earlier estimate (based on measurements of lake-caught lampreys) that the parasitic phase lasts 12 to 18 months; only exceptionally (under conditions of poor growth) may an additional year be required. Lampreys reared to maturity in the laboratory consumed, on the average, 18.5 pounds of fish each. Since they reached only half the weight of "wild" lampreys, the average kill of fish in the lakes may be twice as great.

Observations made during the course of the laboratory rearing of parasitic-phase sea lampreys formed the basis of a doctoral dissertation (University of Michigan) by Lennon on the feeding mechanism and its effect on host fishes. Major aspects of this study were: anatomy of the feeding mechanism; physiological effects of buccal-gland sections on host fish; mechanics of attachment and distribution and gross pathology of wounds; cause of death of host fish. Lennon also succeeded in the artificial fertilization of sea lamprey eggs and reared the young through 21 weeks.

Still another doctoral dissertation (Duke University) was Piavis' descriptive and experimental study of the embryology of the sea lamprey. An important contribution of this research to the control program was the establishment of the rather narrow temperature limits within which

sea lampreys are able to undergo normal development.

Support of research in other institutions.--Financial and technical assistance by Great Lakes Fishery Investigations made possible two additional doctoral studies: Wigley (Cornell University) on the life history of the sea lamprey in Cayuga Lake, New York; Sawyer (University of Michigan) on the physiological effects of various toxicants on sea lamprey larvae. The Hammond Bay laboratory has also supplied extensive materials for research by various institutions and individuals on a number of physiological and morphological problems. In the course of this cooperation, methods were developed for transporting live sea lampreys over great distances.

Development of control methods.

Mechanical barriers.--The major devices tested for blocking or capturing spawning-run sea lampreys were: permanent weirs with removable screens and traps; "demountable" weirs of hardware cloth on wooden frames; barrier dams that cannot be scaled by lampreys because of a retrocurve lip. In addition, a dam with an inclined-screen trap was tested as a means of capturing recently transformed downstream migrants. The principal benefits from these tests were the information gained on sea lampreys and associated fishes and the clear demonstration that lampreys were not to be controlled by mechanical procedures. The weirs and the inclined-screen trap commonly failed in periods of flood (some structures were entirely washed out). Even when weirs could be held the cost of maintenance and operation was excessive. The barrier dam proved effective but its use is limited to the few streams in which it does not cause undue flooding.

Electrical barriers.--The unsatisfactory experiences with mechanical devices led to a start on experimentation with electricity in 1951. In order that the program might be technically sound and efficiently operated, a contract for engineering assistance was negotiated with the Cook Research Laboratories. This laboratory supplied the services first of William A. Stahl and later of Willis L. Nielsen; it also conducted patent searches on uses of electricity for taking, killing, or controlling the movements of fish.

Preliminary experimentation led to the abandonment of electricity as a means of destroying larval lampreys in streambeds or of killing recently transformed lampreys on their downstream migration. Larvae could be driven from the stream bottom by electric shockers but only a fraction left the burrows and few were killed. The resistance of downstream migrants to electricity proved so great that power costs alone would have prevented their destruction by this means even had the engineering problems been solved.

The early experiments in leading fish with electricity revealed the appropriate wave form and duty cycles, but also uncovered difficulties arising from differences in the reactions of fish of various sizes and species. Experimentation with direct current was accordingly abandoned temporarily in favor of the work with alternating current. Studies with direct current were resumed in 1955 in an attempt to reduce the kill of useful fish at certain of the alternating-current barriers in tributaries of Lake Superior. This more recent work has led to the development of equipment in which the direct current is used to repel fish, not to lead them; a cathode array in the stream turns the fish away from the water in which they might be killed by the alternating current. Field tests indicate that this new equipment will put an end to the formerly troublesome fish kills and ultimately may be developed to the point that it can be substituted for alternating-current barriers.

The sea lamprey control program at present is based almost entirely on the blocking of the spawning run with barriers energized with 110-volt alternating current. Shielded traps are constructed along with the barriers to take useful fish which are passed safely upstream. Experimentation on the flow of electricity in water of different electrolytic content (including the development and patenting of a "probe" for measuring voltage gradients) and extensive field testing of electrode arrangements led to thethree types of barriers now in use; parallel arrays of suspended pipe electrodes; single array of suspended pipe electrodes and ground electrodes in the stream bottom; two parallel ground electrodes

on the stream bottom. The type of device is chosen according to stream conditions, and adjustments of equipment are made in accordance with experiences in each stream.

Chemical control.--The reduction of sea lamprey stocks by the prevention of spawning has the disadvantage that benefits are not to be expected until the program has been underway 4 to 6 years. At any one time the stream contains the larvae from that number of previous spawnings. A procedure that can kill all larvae in a single operation, on the other hand, gives almost immediate benefit (only the parasites in the lake remain). In recognition of the need for shortening the time needed to reduce the numbers of sea lampreys, the Hammond Bay Fishery Laboratory in 1953 started a screening program in an attempt to find a compound lethal to ammocoetes in concentrations harmless to fish.

Among the 4,600 compounds tested in the original screening program, 8 were discovered that exhibited strong differential toxicity toward larval lampreys, and of these, 2 gave particular promise. These 2 chemicals were subjected to detailed testing to learn their effects under different physical and chemical conditions and on species of fish other than the rainbow trout and bluegill employed in the original screening. Toxicity studies of structurally related chemicals brought to light 4 additional compounds of promise.

The progress of these chemical studies to the field-testing stage was slow and burdened with numerous setbacks--some expected, others unexpected. A major difficulty has been the arrangement for the synthesis of various chemicals and the development of satisfactory standards of purity. Tests had to be made (by contract with the Wisconsin Alumni Research Foundation) of the effects of the compounds on birds and mammals. Formulations (emulsions, solvents) had to be developed and metering devices obtained and checked. Still further delays were occasioned by the unanticipated sensitivity of some compounds to changes in water conditions, the nature of which has not been exactly determined. Despite all these problems raceway tests were started in late 1956 and large-scale field testing is scheduled for 1957.

Growth of the control program

After the researches at the Hammond Bay Laboratory had led to the development of a practical electrical barrier for blocking sea lamprey runs, it was decided that the initial control experiments should be made on Lake Superior, the only lake that still carried a sufficiently large population of lake trout to support a commercial fishery. This strategy was intended to serve two purposes: prevention of the collapse of still another fishery; preservation of lake trout stocks that could be used in the restoration of Lakes Huron and Michigan. In accordance with this plan, barriers were installed in 10 Lake Superior tributaries before the start of the 1953 run and the control activities were transferred from the Hammond Bay Laboratory to the Marquette field station, under the direction of Erkkila.

Whatever benefits might have accrued from the small-scale control programs of 1953 were lost when operations had to be suspended in mid-June, the barriers dismantled, and the equipment stored. The threat of ruinous budget cuts in fiscal year 1954 that forced this suspension of operations fortunately did not materialize.

The lamprey runs on the U. S. shore of Lake Superior were brought under "full" control in 1954 when the 44 barriers in operation (table 2) blocked all known spawning runs. Actually, the control was not complete. A few short breakdowns occurred, and the discovery of new runs in later seasons indicates that some spawning may have been overlooked. It can be said, nevertheless, that very little lamprey spawning has taken place in U. S. tributaries of Lake Superior subsequent to 1953.

The records of the rate of increase in the abundance of sea lampreys in Lake Superior emphasize the urgent need for effective control. The numbers of spawning-run individuals captured in 30 streams that contained barriers in 1954-56 were:

1954	4,922
1955	8,823
1956	15,753

These figures make it seem likely that the lake

trout fishery, already declining rapidly, may collapse before benefits can be expected from the prevention of spawning. It is greatly to be hoped that the field tests of larvicides will give a means of shortening the time needed to reduce lamprey stocks.

Table 2.--Numbers of electrical sea lamprey control devices in tributaries of Lakes Superior and Michigan, 1953-1956, and numbers scheduled for 1957

Year	Lake Superior	Lake Michigan	Total
1953	10	---	10
1954	44	7	51
1955	46 1/	17	63
1956	48 2/	19	67
1957	54	74 3/	128

1/ 10 held in standby status on basis of previous season's experience
2/ 13 held in standby status on basis of previous season's experience
3/ Scheduled for completion by end of fiscal year 1957

As the number of barriers in spawning streams was increased the costs of maintenance and operation consumed an ever higher percentage of available funds, leaving less and less for new installations. This situation accounts for the slow progress in initiating controls in Lake Michigan--only 7 barriers in 1954, 17 in 1955, and 19 in 1956 (table 2). The greater allotment for fiscal year 1957 (table 1) has permitted the scheduling of 55 new barriers in Lake Michigan tributaries. Plans have been drawn for the rapid completion of the Lake Michigan control system and expansion into the remaining lakes in the succeeding years.

The expansion of the control program required certain administrative changes in 1956: the Supervisor of the program, Erkkila, was transferred to Ann Arbor; (the Assistant Supervisor, B. Smith, continues at Marquette); the Marquette field station was placed under the direction of McLain; a new field station, under the direction of Gaylord was established at Ludington as a center for activities along the eastern shore of Lake Michigan. A field station for the west shore of Lake Michigan at Oconto, Wis., is to be established in early 1957.

Fishery Research Program

Research vessel Cisco

In the year of her launching (1951) the Cisco undertook only one cruise before financial stringencies made it necessary to berth her for the remainder of the season. This 2-week voyage was made in cooperation with the University of Illinois to collect cores and dredge samples of bottom sediments in Lake Michigan.

The actual "shake-down" runs in which the crew and biologists became acquainted with the vessel and its equipment were not made until 1952. In that year extensive limnological observations and experimental fishing were carried out in Green Bay and shorter runs were made in northern Lake Michigan, Lake Huron, and Lake Superior.

The entire 1953 season was spent on a fishery-limnological survey of Lake Superior in which special emphasis was placed on the lake trout--its distribution and abundance in relation to the environment, its life history, and its associates. Through the use of trawling equipment and specially constructed gill nets, trout were taken at early stages not previously studied

in the Great Lakes. Catches from the same gears included large numbers of Coregonus (Prosopium) coulteri, a species not previously reported east of the Pacific slope.

The fishery-limnological surveys of southern Lake Michigan in 1954 and northern Lake Michigan in 1955 had two major goals. First was a precise comparison of chub stocks (species composition, size, abundance, distribution, ...) in 1930-32 and 1954-55; to assure comparable records nets were fished that had specifications identical to those of the experimental gill nets used by the Fulmar in 1930-32. The second goal was the collection of materials and data on all aspects of the limnology--currents, thermal structure, water chemistry, plankton, bottom sediments and organisms, ···. By spending a full season on each of the two sections of the lake both goals were met adequately.

The 1956 season also was spent in a fishery-limnological study of a limited area--Saginaw Bay and adjacent waters of Lake Huron. The principal objective here was to gain information on the ecological conditions and on the distribution and abundance of various species of fish that might throw light on the causes of the poor quality of fishing in the Bay. The program included three 1-day synoptic surveys of the limnology of Saginaw Bay, conducted in cooperation with the Michigan Department of Conservation.

Lake Superior

The Marquette field station was established as the center for fishery research on Lake Superior, but the immediate involvement of the staff with the sea lamprey work and the later (1953) transfer of sea lamprey control to Marquette prevented the development of an organized research program. Although the principal fishery research on Lake Superior has been that conducted from the Cisco, the Marquette staff has made valuable contributions through such activities as: assistance in the tagging and fin-clipping of lake trout; observations on commercial landings of trout--length, weight, incidence of lamprey scars; collection of lake trout scales and stomachs; annual collection of scale samples from the spawning run of lake herring; ···. They have also manned the vessel Siscowet to assist in planting lake trout fingerlings and have done a small amount of experimental fishing.

Lake Michigan

The more recent studies in Lake Michigan were initiated in 1948 when the Fish and Wildlife Service and the Wisconsin Conservation Department entered into a formal agreement (still in effect) for the cooperative study of the fish stocks of southern Green Bay. For the next 2 years this activity was limited to a spring program of tagging yellow perch and the spring and fall collection of scale samples from the principal species (yellow perch, lake herring, whitefish, walleys). Activities were broadened in 1950 with the establishment of a field station at Sturgeon Bay under the direction of Joeris. More satisfactory sampling schedules were set up and observations were extended into the State of Michigan end of Green Bay.

Limitations of funds prevented the addition of biologists needed at Sturgeon Bay. As a result the staff soon was making excellent collections but lacked the time to carry out proper studies of the materials. The station was accordingly closed in 1953 and the activity transferred to Ann Arbor. Field operations have been continued at a level above that of 1948-49 but below that of 1950-53.

Despite the slender support the Green Bay studies received, important accomplishments have been made: a comprehensive life-history study has been completed on the lake herring (doctoral dissertation by S. Smith, University of Michigan); information obtained on yellow perch led to changes of regulations that have doubled production in Wisconsin waters of the Bay; information on the consequences of the phenomenal strength of the 1943 year class of walleyes helped block the passage of unwise restrictions on the fisheries in the State of Michigan waters; a long-term accumulation of materials on various species is laying the groundwork for an effective inquiry into factors of fluctuations.

Prior to the Cisco surveys of 1954 and 1955, research on Lake Michigan proper was limited to the collection of information (by

occasional direct observation and by regular maintenance of records by cooperating fishermen) on catches of lake trout in chub gill nets. These data made it possible to trace the further decline in the lake trout stock after the collapse of the commercial fishery for the species.

Recoveries from the 1944-46 plantings of lake trout fingerlings were the basis of a report on the validity of scale readings and on the growth of trout in Lake Michigan (doctoral dissertation by Cable, University of Michigan).

Lake Huron

Before the Cisco survey of 1956 field work on Lake Huron was limited to the annual collection of scale samples from the spawning runs of the walleye, yellow perch, and lake herring. An interim report has been published on the fluctuations of the walleyes--a continuing study--and a manuscript is nearing completion on the growth and year-class strength of yellow perch (doctoral dissertation by El-Zarka, University of Michigan). No work has been done with the lake herring collections.

Lake Erie

Field work has been limited to the annual fall sampling of the commercial catch at the principal ports. A start has been made on the study of the scales of walleyes, blue pike, and whitefish, but the bulk of the material has not been examined.

Financial and technical aid was given to a study of the life history of the gizzard shad in western Lake Erie (doctoral dissertation by Bodola, Ohio State University).

Lakes Ontario and St. Clair; Red Lakes, Minnesota

No research has been undertaken on Lake Ontario or Lake St. Clair. Some assistance is given studies of the commercial fisheries of the Red Lakes by L. Smith and students, University of Minnesota.

Fishery statistics

A monthly report form with space for daily records of the quantity of gear fished and of the catch of each species, was developed by the Service in the 1920's for use on the Great Lakes. Some states started the use of this form at an early date (Michigan, 1927; Ohio, 1931; Wisconsin, 1936). Others used the form a short time but abandoned it because no use was made of the records; some did not introduce it at all before 1950. When the Great Lakes Fishery Investigations was expanded in 1950, arrangements were made with the states for the use of this "uniform" report throughout the Great Lakes. As part of the agreement the Service compiles and analyzes the records for New York, Pennsylvania, Michigan, Indiana, Illinois, and Wisconsin. Ohio and Minnesota prepare their own tabulations (as does Ontario which also employs the uniform reporting system).

The only routine publication based on the statistical records is the annual compilation of the pounds and value of the catch in U. S. waters (by lake, by state, and by gear) prepared by Great Lakes Fishery Investigations and published by the Branch of Commercial Fisheries. In the main, these records constitute an increasingly valuable backlog of information on local and lake-wide fluctuations in catch, fishing effort, and relative abundance of the principal species to be drawn upon as needed. They have formed the principal materials for papers on the whitefish fishery of Lakes Huron and Michigan, the lake trout fisheries of the upper Great Lakes, the fishery of northern Green Bay, and the chub fishery of Lake Michigan. Other information from the statistical records has been included in various biological publications.

PUBLICATIONS BY STAFF MEMBERS

The following list includes the principal publications of staff members of Great Lakes Fishery Investigations.[4/] Omitted have been

4/ The listing contains 5 papers by Elmer Higgins, who though not actually a member of the Great Lakes staff, had administrative responsibility for the Great Lakes program during his long tenure as Chief of the Branch of Fishery Biology.

papers resulting from work not associated with Great Lakes research, reviews, and numerous processed memoranda and informational releases of only temporary value, prepared for administrative use, or given restricted distribution. The list does include a number of publications of a popular character prepared for the information of the general public and the fishing industry; most of these popular articles contained illustrative original materials drawn from the Great Lakes files or were summaries of longer papers issued in scientific publications not generally accessible.

Applegate, Vernon C.

1950. Natural history of the sea lamprey Petromyzon marinus in Michigan. Fish and Wildlife Serv., Spec. Sci. Rep.:Fish. No. 55, 237 pp.

Exhaustive study of life history from deposition and hatching of eggs, through 4-year larval existence, 1- to 1-1/2-year parasitic stage in lake, upstream spawning migration, and nest building. Contains voluminous ecological data on factors of migration, spawning requirements, larval habitat, ...

1951. The sea lamprey in the Great Lakes. Sci. Monthly, Vol. 72, pp. 275-281. (Revision of Fish and Wildlife Serv., Fish. Leaflet No. 384, issued October 1950.)

Semi-popular account of the invasion of the upper Great Lakes by the sea lamprey and of the effects of that parasite on stocks of commercially valuable fish. Reviews sea lamprey's life history with special reference to technical problems of control.

1951. Sea lamprey investigations. II. Egg development, maturity, egg production, and percentage of unspawned eggs of sea lampreys, Petromyzon marinus, captured in several Lake Huron tributaries. Pap. Mich.Acad.Sci., Arts, and Lett., Vol. 35 (1949), pp.71-90.

Investigation of sex cycle of females--sizes of eggs, number per individual (range of 24,000 to 110,000; mean of 61,500) and its variation with body length and weight, and percentage of unspawned eggs (estimated at 5.0).

Applegate, Vernon C., and Clifford L. Brynildson

1952. Downstream movement of recently transformed sea lampreys, Petromyzon marinus, in the Carp Lake River, Michigan. Trans. Am. Fish. Soc., Vol. 81 (1951), pp. 275-290.

Three-year count of daily catch of newly transformed migrants captured by inclined-plane screen and trap. Includes data on sizes of migrants and evidence of rise in stream water level as major factor inducing migration.

Applegate, Vernon C., John H. Howell, A.E. Hall, Jr., and Manning A. Smith

1957. Toxicity of 4,346 chemicals to larval lampreys and fishes. Fish and Wildlife Serv., Spec. Sci. Rep.:Fish. No. 207, 157 pp.

List of chemicals and record of their effects on ammocetes, rainbow trout, and bluegills at a various low concentration, temperature, 55°F. These tests represent the preliminary work in a search for a means of destroying larval lampreys in streams through the addition of chemicals.

Applegate, Vernon C., Paul T. Macy, and Virgil E. Harris

1954. Selected bibliography on applications of electricity in fishery science. Fish and Wildlife Serv., Spec. Sci. Rep.: Fish. No. 127, 55 pp.

Contains: citations of 350 publications in the worldwide literature, including sources of abstracts and reviews of some; titles of 27 typewritten or processed reports, and locations of agencies with which they are deposited; list of 22 patents issued by the U. S. Patent Office.

Applegate, Vernon C., and James W. Moffett
1955. The sea lamprey. Sci. Am., Vol. 192, No. 4, pp. 36-41.
A concise review of the sea lamprey problem and of research and control operations directed toward its solution. Includes illustrations and diagrams on: spread of the sea lamprey; life cycle; effects on the lake trout fishery; electrical control devices.

1955. Sea lamprey and lake trout, pp. 9-16 in: First Book of Animals (Scientific American), Simon and Schuster, 240 pp.
Review of: sea lamprey's invasion and spread through the upper Great Lakes; life history of the sea lamprey; its impact on fish populations with special reference to lake trout; research aimed at the development of control methods.

Applegate, Vernon C., and Bernard R. Smith
1950. Sea lamprey spawning runs in the Great Lakes, 1950. Fish and Wildlife Serv., Spec. Sci. Rep.: Fish. No. 61, 49 pp.
Records of numbers, sex ratio, sizes, ... of adult and recently transformed sea lampreys captured in experimental weirs and traps operated in various streams tributary to Lakes Michigan, Huron, and Superior.

1951. Movement and dispersion of a blocked spawning run of sea lampreys in the Great Lakes. Trans. 16th N. Am. Wildlife Conf., pp. 243-251.
Analysis of data on 289 recoveries from 2,843 sea lampreys tagged after capture below a dam in the Cheboygan River (tributary to Straits of Mackinaw). Lampreys lack "homing" instinct.

Applegate, Vernon C., Bernard R. Smith, Alberton L. McLain, and Matt Patterson
1952. Sea lamprey spawning runs in the Great Lakes, 1951. Fish and Wildlife Serv., Spec. Sci. Rep.: Fish. No. 68, 37 pp.
Record for 1951 similar to that for 1950 (Applegate and Smith 1951). Includes data on annual trends in numbers, sizes, and sex ratio runs.

Applegate, Vernon C., Bernard R. Smith, and Willis L. Nielsen
1952. Use of electricity in the control of sea lampreys: electromechanical weirs and traps and electrical barriers. Fish and Wildlife Serv., Spec. Sci. Rep.: Fish. No. 92, 52 pp.
Account of 1951-1952 experiments with electrical barriers for blocking sea lamprey spawning runs. Describes installation and operation of four devices and their effects on sea lampreys and fish. Summarizes the problem of adapting construction and operation according to local stream conditions.

Cable, Louella E.
1950. A cheek tag for marking fish, with semi-automatic pliers for application of tag. Jour. du Cons., Vol. 16, pp. 185-191.
Description of tag, composed of steel rivet and plastic disc, and of pliers designed for its application.

1956. Validity of age determinations from scales, and growth of marked Lake Michigan lake trout. Fish Bull., Fish and Wildlife Serv., Vol. 57, pp. 1-59.
The structure and growth of lake trout scales are described and illustrated by a series of photographs. The general validity of the annulus as a year-mark is established by scales of fish of known ages recovered from plantings of fin-clipped fingerlings made in Lake Michigan in 1944, 1945, and 1946. Included also are data and discussion on: growth of marked fish; factors of discrepancies of calculated growth; time of annulus formation; progress of season's growth; length-weight relation.

Deason, Hilary J.

1932. Scientific investigation of chubnet fishing in Lake Michigan. The Fisherman, Vol. 1, No. 4, pp. 3-4 and 11-12.
Description of organization and program of researches carried out from the research vessel Fulmar in cooperation with the States of Michigan and Wisconsin and four net manufacturers, and statement of principal goal as determination of mesh size most suitable for exploiting chubs and least harmful to immature lake trout.

1932. A study of surface currents in Lake Michigan. The Fisherman, Vol. 1, No. 5, pp. 3-4 and 12.
Summary of information on direction and speed of surface currents obtained from recoveries of 180 of the 283 drift bottles released from the research vessel Fulmar, June-August 1931.

1933. Preliminary report on the growth rate, dominance, and maturity of the pike-perches (Stizostedion) of Lake Erie. Trans. Am. Fish. Soc., Vol. 63, pp. 348-360.
Comparison of growth of walleyes, blue pike, and sauger. Includes also data on dominance of the 1926 year class and on size at maturity for the three species.

1933. Geological formation of Great Lakes. The Fisherman, Vol. 2, No. 3, pp. 3-4 and 10.
Review of major stages and drainage patterns in the geological history of the Great Lakes.

1933. Feeding adaptations in fishes. The Fisherman, Vol. 2, No. 7, pp. 3-4 and 10-11.
Anatomical comparison of various types of feeding mechanism of fishes.

1934. The development of fishes, tracing the natural developments from egg to fry. The Fisherman, Vol.3, No. 11, pp. 1 and 3.
Description of embryological development based on eggs and fry of the walleye.

1935. Some general considerations of plankton and plankton problems with reference to water supplies. Eng. Exp. Sta. Bull., Mich. State Coll., Vol. 10, No. 4, pp. 5-14.
General discussion of such matters as factors of plankton production, vertical distribution, seasonal abundance, relation of plankton growth to odors and tastes in water, and effect of pollution on plankton growth.

1936. Bottles set adrift on Lake Michigan yield information on surface currents. Mich. Cons., Vol. 6, No. 6, p. 9.
Review similar to that published by same author in 1932.

1939. The distribution of cottid fishes in Lake Michigan. Pap. Mich. Acad. Sci., Art, and Lett., Vol. 24, pt. 2 (1938), pp. 105-115.
Distributional study in which many of the locality records, particularly for deep-water species, were based on specimens recovered from stomachs of lake trout and burbot.

Deason, Hilary J., and Ralph Hile

1947. Age and growth of the kiyi, Leucichthys kiyi Koelz, in Lake Michigan. Trans. Am. Fish. Soc., Vol. 74 (1944), pp. 88-142.
Comparative study for different regions of the lake which revealed no important differences in growth but a progressive increase from south to north in average age. Includes data on such questions as causes of discrepancies between calculated growths of different age groups, length of growing season, growth compensation, length-weight relationship and condition (including seasonal fluctuations and regional differences), and sex ratio.

Duden, William R.

1933. . Recent advances in the fishing industry. Part I, The Fisherman, Vol. 2, No. 10, pp. 3-4 and 10-11; Pt. II, Vol. 2, No. 12, pp. 3-4 and 10. (Reference to Part II is for first of two issues labeled No. 12.)

Summary of developments in processing, transportation, marketing, advertising, and the utilization of by-products.

Erkkila, Leo F., Bernard R. Smith, and Alberton L. McLain

1956. Sea lamprey control on the Great Lakes 1953 and 1954. Fish and Wildlife Serv., Spec. Sci. Rep.--Fish. No. 175, 27 pp.

Summary of operations of electrical control devices in tributary streams along the south shore of Lake Superior and in northern Green Bay, Lake Michigan. Lists numbers of lampreys and fish taken in different streams and discusses the problem of minimizing the kill of useful species. Includes biological data on lamprey runs.

Eschmeyer, Paul H.

1953. The effect of ether anesthesia on fin-clipping rate. Prog. Fish-Cult., Vol. 15, No. 2, pp. 80-82.

Comparisons of clipping rate for individual operators on alternate days when ether was and was not used indicated that anesthesia improved the number of lake trout fingerlings marked per hour by 75 to 100 fish or approximately 28 percent. Differences between anesthetized and unanesthetized fish with respect to quality of mark and post-marking mortality were small.

1955. The reproduction of lake trout in southern Lake Superior. Trans. Am. Fish. Soc., Vol. 84 (1954) pp. 47-74.

Presents data on : spawning seasons and grounds; size at maturity; sex ratio and size distribution of spawning fish; "homing" instinct of local stocks; fecundity of "lean" lake trout and of siscowets; relative accuracy of three methods of estimating the numbers of eggs in ovaries.

1956. The early life history of the lake trout in Lake Superior. Mich. Dept. Cons., Inst. Fish. Res., Misc. Pub. No. 10, 31 pp.

Materials collected by trawls and experimental gill nets yielded information on various phases of the life history during the first 3 years of life. Includes data on: abundance; bathymetric distribution and seasonal movements; progress of season's growth; annual increments; local differences of growth; sex ratio; food habits according to size of fish; associated species of fish.

1957. The near extinction of lake trout in Lake Michigan. Trans. Am. Fish. Soc., Vol. 85 (1955), pp. 102-119.

Following the collapse of the commercial fishery for lake trout in Lake Michigan in the late 1940's, the further decline of the trout stocks was traced from records of small fish caught in small-mesh gill nets fished for chubs. By 1951 the abundance was only 4 percent of that prior to the sea lamprey invasion and by 1955 the trout was near extinction--only 8 fish were caught in 5-1/2 million linear feet of gill nets. Evidence is given that legal-sized (1-1/2 pounds and larger) and small trout declined at similar rates and that lampreys, not commercial fishing, were responsible for that decline.

1957. Note on subpopulations of lake trout in the Great Lakes. In: Contributions to the study of subpopulations of fishes. Fish and Wildlife Serv., Spec. Sci. Rep.--Fish. No. 208, p. 129.

A brief statement of evidence of the existence of subpopulations of lake trout in the Great Lakes. This problem has received little study and

opportunities for investigation have disappeared or are dwindling rapidly because of the destruction of lake trout stocks by the sea lamprey.

Eschmeyer, Paul H., and Reeve M. Bailey
1955. The pygmy whitefish, Coregonus coulteri, in Lake Superior. Trans. Am. Fish. Soc., Vol.84 (1954), pp. 161-199.
Discovery of a large population of pygmy whitefish in Lake Superior extended the known range 1,100 miles. The morphology of the Lake Superior stock is compared with that of other populations. Information is given for the Lake Superior stock with respect to: geographic distribution and local abundance; bathymetric distribution; length frequencies; age and growth; sex ratio; maturity; fecundity; spawning; food; associates.

Eschmeyer, Paul H., and Walter R. Crowe
1955. The movement and recovery of tagged walleyes in Michigan, 1929-1953. Mich. Dept. Cons., Inst. Fish. Res., Misc. Pub. No. 8, 32 pp.
Report on recaptures from 14,000 walleyes tagged in various State of Michigan waters over a 25-year period. Kind and extent of movements varied according to the conditions of the experiments. Walleyes tagged in the Muskegon River scattered widely through Lake Michigan; many were recovered 100-175 miles from the point of tagging. Tags depressed the rate of growth.

Eschmeyer, Paul H., Russell Daly, and Leo F. Erkkila
1953. The movement of tagged lake trout in Lake Superior, 1950-1952. Trans. Am. Fish. Soc., Vol. 82 (1952), pp. 68-77.
Recoveries from 733 native lake trout tagged at Cornucopia, Wisconsin, and off the Keweenaw Peninsulaamounted to 155 fish or 21.1 percent. Percentages of recapture for different kinds of tags were: aluminum, lower jaw, 10.7; monel, upper jaw, 14.0; streamer, 19.8; Peterson, 45.4. Large fish moved greater distances before recapture than did small ones. Many fish crossed state lines and a few were captured in Canadian waters.

1953. Movement of tagged lake trout in Lake Superior, 1950-1952. The Fisherman, Vol. 21, No. 3, pp. 4 and 11.
Condensed version of 1953 paper of the same authors under a similar title.

Gallagher, Hubert R., and John Van Oosten
1943. Supplemental report of the United States members of the International Board of Inquiry for the Great Lakes Fisheries. Rep. Internat. Bd. Inq. Great Lakes Fish.--Rep. and Suppl., pp. 25-213.
A major source of information on the Great Lakes fisheries. Body of report includes detailed treatment of: trends of production; evidence of and factors contributing to depletion; problems of regulation and management; history of the many unsuccessful attempts to attain adequate and uniform regulations; need for international investigation and control. Appendices include selected bibliography on the Great Lakes fisheries and complete record of all available statistics on production through 1940 (many of these statistics compiled from original records and published for the first time).

Gallagher, Hubert R., A.G. Huntsman, D.J. Taylor, and John Van Oosten
1943. Report of the International Board of Inquiry for the Great Lakes Fisheries. Rep. Internat. Bd. Inq. Great Lakes Fish.--Rep. and Suppl., pp. 1-24.
General review of management and research problems concluding with recommendations for: common investigation of the fisheries; joint regulation and management of stocks found to be common; provisions for

collection of complete and accurate statistics; tests of effectiveness of planting fish.

Hall, A.E., Jr., and Oliver R. Elliott
1954. Relationship of length of fish to incidence of sea lamprey scarring on white suckers, Catostomus commersoni, in Lake Huron. Copeia 1954, No. 1, pp. 73-74.
Percentages of white suckers with lamprey scars at various lengths were: 5.0-10.9 inches, 11.0; 11.0-14.9 inches, 40.1; 15.0-20.9 inches, 70.6 percent. Incidence of multiple scars also increased with length of fish. These relations are attributed to: mechanical difficulty of lamprey attachment to the smaller fish; greater ability of the larger fish to survive attack; greater length of time larger fish have been exposed to attack.

Higgins, Elmer
1928. Conference of Lake Erie biologists. Science, Vol. 67, pp. 309-310.
Report on meeting at Cleveland on February 6, 1928, of representatives of federal, state, and provincial research agencies and of scientific and educational institutions to formulate and coordinate plans for limnological and fishery investigations of Lake Erie.

1928. Cooperative fishery investigations in Lake Erie. Sci. Monthly, Vol. 27, pp. 301-306.
General discussion of problems and goals of fishery research and an outline of cooperative researches on Lake Erie under the three general divisions: analysis of statistics of yield in relation to fishing intensity; life-history studies (age, growth, mortality, migration, food, ···) of important species; limnological and ecological inquiries with special reference to pollution problems.

1929. Can the Great Lakes fisheries be saved? Outdoor America, Vol. 7, No. 8, pp. 34-35.
Comments on the unique value and importance of the Great Lakes fisheries, explanation of decreasing productivity as the result of overfishing, and statement that adequate and uniform regulations are needed to conserve and restore the stocks.

1938. The ineffectiveness of regulation of the Great Lakes fisheries by the individual states. Proc. Great Lakes Fish. Conf., Detroit, Mich., Feb. 25-26, 1938, Council of State Governments, pp. 48-60.
Review of bacteriological and limnological studies refuting contention that pollution has been a significant factor in the decline of Great Lakes fisheries, outline of evidence that overfishing has been the major cause, and comments on the impossibility of adequate regulation under divided control by the individual states.

1938. Fish outlive officials. State Government, Vol. 11, pp. 53-54 and 58.
Summary of arguments in support of belief that overfishing caused depletion of Great Lakes fisheries, review of past failures to attain adequate regulations through voluntary cooperation of state and provincial agencies, and recommendation for establishment of central control by means of international treaty.

Hile, Ralph
1932. Fish scales and commercial fisheries. The Fisherman, Vol. 1, No. 10, pp. 3-4 and 10.
Description of methods of determining age and growth from scales and examples of application to fishery problems.

1934. Causes of variation in the growth rates of fishes. The Fisherman, Vol. 3, No. 2, pp. 3-4 and 10-11.
Discussion of growth types and of major factors responsible for growth differences in different populations and for fluctuations in growth within a single stock.

Hile, Ralph

1935. Daily reports reveal new facts and figures. The Fisherman, Vol. 4, No. 12, pp. 1-2.
Description of relationship between fishing time and catch of fish in various types of stationary gear. Suggests that increase of catch with increase of nights out is so small that frequent lifting will give most efficient use of gear.

1936. Low production may not mean depletion. The Fisherman, Vol.5, No. 2, pp. 1-2.
Demonstration, from comparison of annual fluctuations of total yield and of catch per net, of danger of estimating abundance from production statistics.

1936. Age determination of fish from scales; method and applications to fish cultural problems. Prog. Fish-Cult., Bur. Fish. Memo. 1-131, No. 23, pp. 1-5.
Description of methods in age-and-growth studies, with comments on usefulness of growth data in management of waters, with special reference to planting programs.

1936. Age and growth of the cisco, Leucichthys artedi (Le Sueur), in the lakes of the northeastern highlands, Wisconsin. Bull. U.S.Bur. Fish., Vol. 48, pp. 211-317.
Comparison of four populations as to growth rate, condition, sex ratio, ... in relation to such factors as population density, abundance of plankton, and physical-chemical conditions in lakes. In order of arrangement growth rate was correlated negatively with population density and concentration of bound CO_2, and condition was correlated negatively with the abundance of plankton. Differences among stocks as to length of growing season contributed to differences of growth rate. The relative abundance of females was greater in slow growing than in fast growing stocks and increased with age.

1936. Summary of investigations on the morphometry of the cisco, Leucichthys artedi (Le Sueur), in the lakes of the northeastern highlands, Wisconsin. Pap. Mich. Acad. Sci., Arts, and Lett., Vol. 21 (1935), pp. 619-634.
Summary of research reported in full in 1937 paper.

1937. Morphometry of the cisco, Leucichthys artedi (Le Sueur), in the lakes of the northeastern highlands, Wisconsin. Internat. Rev. der ges. Hydrob. und Hydrog., Bd. 36, Heft 1/2, S. 57-130.
Comparison of morphological characteristics of four stocks of widely differing growth rates. Present elaborate division of artedi into subspecies is held to be without demonstrated validity by reason of: negative correlation, both between and within stocks, between growth rate and eye diameter, and length of head, maxillary, paired fins, and dorsal fin; progressive change of body proportions with increase in length; and existence of significant differences between year classes of same stock in both proportions and numerical characters.

1937. The increase in the abundance of the yellow pikeperch, Stizostedion vitreum (Mitchill), in Lakes Huron and Michigan, in relation to the artificial propagation of the species. Trans. Am. Fish. Soc., Vol. 66 (1936), pp. 143-159.
Comparison of plantings of yellow pikeperch (walleyes) with later production and abundance (on catch-per-net basis) to estimate value of artificial propagation. No evidence of benefits was found.

1941. Age and growth of the rock bass, Ambloplites rupestris (Rafinesque), in Nebish Lake, Wisconsin. Trans. Wis. Acad. Sci., Arts, and Lett., Vol. 33, pp. 189-337.
Study of fluctuations in growth and strength of year classes of rock bass in a 95-acre landlocked lake. Growth

was correlated positively with temperatures in June and September (terminal months of the growing season) and with precipitation in June. The strength of year classes was correlated positively with temperature and precipitation in May, June, and July. Other topics treated include: criteria for testing validity of annulus as a year-mark; sex and age differences in progress of season's growth; growth compensation as a real and as an "apparent" phenomenon; relation of growth rate to size and age at maturity; annual and seasonal fluctuations in the length-weight relationship; sex ratio.

1942. Growth of the rock bass, Ambloplites rupestris (Rafinesque) in five lakes of northeastern Wisconsin. Trans. Am. Fish. Soc., Vol. 71 (1941), pp. 131-143.

Comparison of growth and length-weight relationship in different populations. Growth curves of rock bass from lakes with medium-hard to hard water were more distinctly sigmoid and had larger increments in later years of life than curves for stock from soft-water lake. Order of the stocks with respect to relative heaviness followed the order of the lakes as to hardness of water.

1943. Mathematical relationship between the length and the age of the rock bass, Ambloplites rupestris (Rafinesque). Pap. Mich. Acad. Sci., Arts, and Lett., Vol. 28 (1942), pp. 331-341.

Derivation of equation on the assumption that annual percentage growth in length decreases at a constant percentage rate, and application to growth of two stocks of rock bass. Equation, $L = K(CB + 1)(CB^2 + 1)(CB^3 + 1)\cdots(CB^t + 1)$, where L = length, t = age in years, and K, C, and B = constants fitted growth of one stock through 9 years of life; in another the equation fitted over 6 years but yielded values that were too high for the seventh, eighth, and ninth years.

1948. Standardization of methods of expressing lengths and weights of fish. Trans. Am. Fish. Soc., Vol. 75 (1945), pp. 157-164.

Recommendation for uniform use of total length (tip of head, mouth closed, to tip of tail, lobes compressed) and for English units of weight and measurement (with decimal fractions) in all but highly technical papers.

1949. Trends in the lake trout fishery of Lake Huron through 1946. Trans. Am. Fish. Soc., Vol. 76 (1946), pp. 121-147.

Review of available statistics on production, 1879-1946, and detailed treatment of annual fluctuations in production, abundance, and fishing intensity in local districts of the U. S. waters, 1929-1946, with special reference to the decline that followed the invasion and spread of the sea lamprey.

1950. Green Bay walleyes. A report on the scientific investigation of the marked increase in abundance of walleyes in Green Bay. The Fisherman, Vol. 18, No. 3, pp. 5-6.

Popular discussion pointing out: that the abnormally high abundance could be traced almost entirely to a single year class (1943); that a return to a much lower level could be considered inevitable; and that restrictive regulations, intended to perpetuate the abnormal abundance would prove disappointing and would place unnecessary handicaps on the fishing industry.

1950. A monograph for the computation of the growth of fish from scale measurements. Trans. Am. Fish.Soc., Vol. 78 (1948), pp. 156-162.

Description of a device usable for rapid nomographic computation of growth from scale measurements regardless of the nature of the body-scale relationship.

1952. Fishing regulations. The Fisherman, Vol. 20, No. 3, pp. 5, 12, and 14.

Address to fishermen's associations of Michigan and Wisconsin suggesting possibility of control of fishing intensity through limitation of number of licenses as substitute for the "legally imposed inefficiency" of certain restrictive measures and calling for scientific inquiry into soundness of assemptions as to proper size limits, closed seasons, ···on which current regulations are based.

1952. 25 years of Federal fishery research on the Great Lakes. Fish and Wildlife Serv., Spec. Sci. Rep.--Fish. No. 85, 48 pp.

The original article of which the present one is a revision and expansion.

1952. Changes in the lake trout fishery of the three upper lakes. The Fisherman, Vol. 20, No. 6, pp. 5 and 8.

Comparison of production by state and province in Lakes Michigan, Huron, and Superior in 1949 and 1950. Gives details for these two years on production, fishing intensity, and abundance of lake trout in the six statistical districts of the State of Michigan waters of Lake Superior. Records of catch per unit effort of gill nets, pound nets, and set-hooks indicated that use of nylon gill nets had not yet biased statistics seriously in 1950.

1953. Perch studies in Green Bay. Prog. Fish.-Cult., Vol. 15, No. 3, pp. 133-134.

The studies were started cooperatively by the Fish and Wildlife Service and the Wisconsin Conservation Department in 1948 to learn causes of poor fishing and to obtain a better basis for management. Evidence that growth was so slow that few fish survived to reach the minimum legal length of 8 inches led to a lowering of the limit to 7-1/2 inches in 1952. During the 1952 season fishermen kept 250 fish for every 100 they could have retained under the former limit. No effects could be detected on the perch population.

1953. Trout fishing in Michigan waters of Lake Superior, 1952. The Fisherman, Vol. 21, No. 5, pp. 7, 11-12, and 14.

Description of trends of production, fishing intensity, and abundance in the six statistical districts of State of Michigan waters, 1949 through 1952. Analyses of catch per unit effort after general change from cotton to nylon gill nets led to suggestion that gill nets draw on a different segment of the population than that exploited by pound nets and set-hooks.

1954. Fluctuations in growth and year-class strength of the walleye in Saginaw Bay. Fish. Bull., Fish and Wildlife Serv., Vol. 56, pp. 7-59.

Collections of 1926-1930 yielded information on the relative strength of year classes in 1917-1928 and on fluctuations of growth in length and weight in 1916-1929. A single collection in 1943 provided some information on these matters for later years and demonstrated a large increase of growth rate and decrease of average age after 1929. Paper includes data on commercial production, length-weight relation, sex ratio, and size at maturity.

1954. Changing concepts in fishery research on the Great Lakes. Proc. Gulf and Caribbean Fish. Inst., 6th Ann. Sess., pp. 64-70.

The approach in earlier research was biased by undue emphasis on depletion through overfishing as the major, perhaps the only significant factor in the progressive deterioration of the Great Lakes fisheries. Too little attention was given to effects of selective fishing, species interactions, and environmental changes. It is now realized that populations should be studied as a whole, all species together in relation to their changing environment. In this complex situation, application of modern fishing theory offers little promise of profitable return.

1954. Status and future of the American Fisheries Society. Trans. Am. Fish. Soc., Vol. 83 (1953), pp. 357-359.

Presidential address at eighty-third annual meeting urging: a more democratic organization, the wielding of greater influence in fishery matters of general public concern; the ending of the trend toward superficiality in research.

1955. The walleye problem in Green Bay. Prog. Fish.-Cult., Vol. 17, No. 1, p. 44.

Review of the consequences of the phenomenal strength of the 1943 year class--enormous increases of production and fishing pressure, frictions among groups of commercial operators and between commercial and sport fishermen, and use of scientific information on walleyes in preventing passage of unwise restrictive legislation.

Hile, Ralph, and Howard J. Buettner

1955. Commercial fishery for chubs (ciscoes) in Lake Michigan through 1953. Fish and Wildlife Serv., Spec. Sci. Rep.--Fish. No. 163, 9 pp.

Historical review of a fishery based on seven deep-water species of coregonids. Includes the fragmentary and scattered statistics of 1890 1925, the continuous and more dependable catch statistics of 1926-1954, and data on catch, fishing intensity, and abundance in local areas for Michigan (1929-1954), Wisconsin (1953-1954), and Illinois (1950-1954). Discusses: biasing effects of changes in fishing laws and of types of gill-net twine (linen, cotton, nylon) on estimation of abundance; comments on deterioration of the fishery resulting from the end of lake trout predation on small chubs, the attacks of sea lampreys on large chubs, and the large increase in fishing intensity. Data for 1954 in an appendix.

Hile, Ralph, and Hilary J.Deason

1934. Growth of the whitefish, Coregonus clupeaformis (Mitchill), in Trout Lake, northeastern highlands, Wisconsin. Trans. Am. Fish. Soc., Vol. 64, pp. 231-237.

Description of growth of a "dwarf" population of whitefish and a comparison with growth in other waters.

1947. Distribution, abundance, and spawning season and grounds of the kiyi, Leucichthys kiyi Koelz, in Lake Michigan. Trans. Am. Fish. Soc., Vol. 74 (1944), pp. 143-165.

Analysis of catch data from experimental gill nets for records of geographic distribution and study of vertical distribution and regional abundance. Kiyi established as deep-water form taken in numbers in less than 50 fathoms only at times of unusual hydrographic disturbances. Abundance determined to be nearly uniform throughout great central basins, but species found to be scarce in northeastern island area. Spawning-run samples indicated no movement toward inshore waters and a spawning season extending from late September to mid-November or later.

Hile, Ralph, and William R. Duden

1933. Methods for the investigation of the statistics of the commercial fisheries of the Great Lakes. Trans. Am. Fish. Soc., Vol.63, pp.292-305.

Account of tentative procedures for compilation and analysis of commercial fishery statistics. Includes a definition of "effective fishing effort" for use in fisheries based on a variety of species.

Hile, Ralph, Paul H. Eschmeyer, and George F. Lunger

1951. Decline of the lake trout fishery in Lake Michigan. Fish. Bull., Fish and Wildlife Serv., Vol. 52, pp. 77-95.

Statistical study of the lake trout

fishery similar to that made by Hile (1949) for Lake Huron. Detailed records of fishing pressure in 1929-1949 proved that overfishing could not have been a significant factor in decline of lake trout in State of Michigan waters of Lake Michigan and contributed to conclusion that sea-lamprey depredations offered the only reasonable explanation.

1951. Decline of the trout fishery in Lake Michigan. The Fisherman, Vol. 19, No. 1, pp. 5 and 10.
Summary of longer paper published by same authors under similar title in same year.

1951. Status of the lake trout fishery in Lake Superior. Trans. Am. Fish. Soc., Vol. 80, (1950), pp. 278-312.
Review similar to that in other 1951 article by same authors for Lake Michigan. No evidence existed of injury to lake trout in Lake Superior by sea lamprey through 1949. Stocks were nevertheless in precarious condition as result of long-term trends which had led to excessively high fishing pressure and abnormally low availability in State of Michigan waters (and probably in other regions of lake) by that year.

1951. Status of the lake trout fishery in Lake Superior. The Fisherman, Vol. 19, No. 3, pp. 5 and 13.
Summary of longer paper published by same authors under same title in same year.

Hile, Ralph, and Frank W. Jobes
1941. Age, growth, and production of the yellow perch, Perca flavescens (Mitchill), of Saginaw Bay. Trans. Am. Fish. Soc., Vol. 70 (1940), pp. 102-122.
Analysis of production records, 1891-1938, and of annual fluctuations in abundance and fishing intensity, 1929-1938, and life-history study with data on body-scale relationship, age and size, growth, length-weight relationship, and sex ratio.

1942. Age and growth of the yellow perch, Perca flavescens (Mitchill), in the Wisconsin waters of Green Bay and northern Lake Michigan. Pap. Mich. Acad. Sci., Arts, and Lett., Vol. 28 (1941), pp. 241-266.
Investigation of such phases of the life history as age and size, growth in length and weight, length-weight relationship, sex ratio, and maturity, and a comparison indicating growth rates to be similar in southern Green Bay and northwestern Lake Michigan proper, but much slower in both areas than in Saginaw Bay and Lake Erie.

Hile, Ralph, and Chancey Juday
1941. Bathymetric distribution of fish in lakes of the northeastern highlands, Wisconsin. Trans. Wis. Acad. Sci., Arts, and Lett., Vol. 33, pp. 147-187.
Comparison of bathymetric distribution of fish in four lakes, revealing a wide variation from one water to another and, except for the cisco, a lack of clear-cut dependence of that variation on such factors as temperature and concentrations of dissolved oxygen and free carbon dioxide.

Hile, Ralph, George F. Lunger, and Howard J. Buettner
1953. Fluctuations in the fisheries of State of Michigan waters of Green Bay. Fish. Bull., Fish and Wildlife Serv., Vol. 54, pp. 1-34.
Comparison of production levels and trends in 1885, 1891-1908, and 1929-1949 and description of relations of fluctuations in production, abundance, and fishing intensity in last period. Questions soundness of interpreting decline in mean annual take of all species from 7 million pounds in 1891-1908 to 3-1/2 million pounds in 1929-1949 as result of overfishing; the relatively cheap lake herring alone more than accounted for the decrease whereas the average annual take of more prized varieties increased (for example, annual yield of the valuable whitefish in 1929-1949 was 4-1/2 times that in 1891-1908). Concludes with discussion

of the problem of regulation.

Jobes, Frank W.

1932. Deep trapnets on Lakes Huron and Michigan. The Fisherman, Vol. 1, No. 3, pp. 3-4.

An outline of the cooperative program (with the Michigan Department of Conservation) to study the effects of this new and unusually efficient net on stocks of whitefish.

1933. Preliminary report on the age and growth of the yellow perch (Perca flavescens Mitchill) from Lake Erie, as determined from a study of its scales. Pap. Mich. Acad. Sci., Arts, and Lett., Vol. 17 (1932), pp. 643-652.

Brief report on analysis of first two years' collections in life history study, including data on age composition (evidence of phenomenal strength of 1926 year class) and growth in length and weight.

1943. The age, growth, and bathymetric distribution of Reighard's chub, Leucichthys reighardi Koelz, in Lake Michigan. Trans. Am. Fish. Soc., Vol. 72 (1942), pp. 108-135.

Life-history and distributional study based on 1930-1932 collections by experimental gill nets. Reighard's chub spawned in May and June at 20-79 fathoms; in other months was most plentiful at 20-60 fathoms. Abundance on east shore of lower half of lake was seven times that on west shore and three times that in northern part of lake. Age-group IV (average length 10.9 inches; average weight 6.1 ounces) dominated samples. Females outnumbered males and survived to greater age.

1949. The age, growth, and bathymetric distribution of the bloater, Leucichthys hoyi (Gill), in Lake Michigan. Pap. Mich. Acad. Sci., Arts, and Lett., Vol. 33, (1947), pp. 135-172.

Study of distribution from 1930-1932 collections from experimental gill nets and of growth from earlier (1919 and 1928) collections from Grand Haven, Michigan. Bloaters were most plentiful at 20-59 fathoms (with the larger fish in the deeper water in some months); abundance on east shore of lower part of lake was 1-1/2 times that on west shore and 2-1/3 times that in northern part of lake. Samples were dominated by age-group IV in 1919 and (weakly) by age-group II in 1928. Growth was slightly more rapid in females than in males but was slow in both sexes (barely 8 inches in 5 years). Females outnumbered males.

1949. The age, growth, and distribution of the longjaw cisco, Leucichthys alpenae Koelz, in Lake Michigan. Trans. Am. Fish. Soc., Vol. 76 (1946), pp. 215-247.

Study of distribution from 1930-1932 collections from experimental gill nets and of growth from earlier (1923 and 1928) collections. Longjaw was most plentiful at less than 70 fathoms and more than four times as abundant in northern part of lake and along east shore as on west shore of lower lake. Samples were dominated by age-groups III or IV. Growth was similar off Grand Haven, Michigan, and in northeastern Lake Michigan (average length about 11 inches and average weight about 6-1/4 ounces at end of 4 years). Sex ratio was variable but females generally outnumbered males and reached higher ages.

1952. Age, growth, and production of yellow perch in Lake Erie. Fish. Bull., Fish and Wildlife Serv., Vol. 52, pp. 205-266.

Review of production statistics, 1885-1947, and detailed life history study. Includes materials on validity of scale readings, body-scale relationship, size and age distribution, growth (including annual fluctuations, length of growing season, and growth compensation), length-weight relationship and condition (including fluctuations by month and year and according to age and sexual state), maturity, and sex ratio.

Joeris, Leonard S.

1953. Technique for the application of a streamer-type fish tag. Trans. Am. Fish. Soc., Vol. 82 (1952), pp. 42-47.

Principal features of the technique are: attachment of tag by a nylon-thread loop prepared in advance of field work; application of tag by means of a curved surgical needle with a cutting edge and a split eye. Preparation of needle and tagging procedure are described.

1957. Structure and growth of scales of yellow perch of Green Bay. Trans. Am. Fish. Soc., Vol. 86 (1956), pp. 169-194.

Scales are described and their use for age determination validated by comparisons of ages of younger fish or read from scales and estimated from modes in length distribution. Annual and local variations in the time of annulus formations are described. Body-scale curves are presented for "key" scales above and below the lateral line. Body-scale curves based on the same key scale are compared for yellow perch of Lake Erie, Saginaw Bay, and Green Bay.

Koelz, Walter N.

1921. Description of a new cisco from the Great Lakes. Occ. Pap. Mus. Zool., Univ. Mich., No. 104, 4 pp.

Original description of Leucichthys kiyi--type collected in Lake Michigan 12 miles ExS from Sturgeon Bay Ship Canal, August 23, 1920.

1924. Two new species of cisco from the Great Lakes. Occ. Pap. Mus. Zool., Univ. Mich., No. 146, 8 pp.

Original description of Leucichthys alpenae--type collected in Lake Michigan, 22 mile NNE of Charlevoix, Michigan, June 15, 1923--and of Leucichthys reighardi--type collected in Lake Michigan, 18 miles NxW of Michigan City, Indiana, April 1, 1921.

1925. Description of a new cisco from the Great Lakes basin. Occ. Pap. Mus. Zool., Univ. Mich., No. 158, 3 pp.

Original description of Leucichthys nipigon--type collected from Lake Nipigon off MacDiarmid, July 28, 1922.

1926. Fishing industry of the Great Lakes. Rep. U. S. Comm. Fish. for 1925, pp. 553-617.

General account of the fisheries. Introductory section on boats, gear, organization, and products is followed by sections giving for individual lakes: brief description of lake; history of development of fishery; fishing districts; description of fishery for individual species; summary of regulations on gear, size limits, and closed seasons.

1928. Fisheries of the Great Lakes. General review. In: Progress in biological inquiries, 1926, by Elmer Higgins. Rep. U.S. Comm. Fish. for 1927, pp. 660-662.

Brief comments on a variety of subjects, including: productivity of the different lakes in pounds per square mile, importance of taxonomic study of coregonids, a group contributing half of the total Great Lakes catch; collapse of the Lake Erie cisco fishery; evidences of general depletion and need for international regulation of the Great Lakes fisheries.

1929. Coregonid fishes of the Great Lakes. Bull. U. S. Bur. Fish., Vol. 43 (Pt. 2), pp. 297-643.

Monographic taxonomic, and natural history study of coregonids of Great Lakes and Lake Nipigon. Includes extensive data on morphological variation, geographical and bathymetric distribution, food, size, maturity, and spawning seasons and grounds. Discusses problem of origin and speciation in coregonids of the Great Lakes basin.

1931. The coregonid fishes of northeastern America. Pap. Mich. Acad. Sci., Arts, and Lett., Vol. 13 (1930), pp. 303-432.

An elaborate systematization of coregonids of the area. Divides Leucichthys artedi into 24 subspecies (17 described as new), Coregonus clupeaformis into 7 subspecies (4 new), and Prosopium quadrilaterale into 2 subspecies (1 new). Includes also original description of Leucichthys bartletti.

Krumholz, Louis A., and Ralph Hile
1944. Fillet weights and loss in filleting of yellow pikeperch, Stizostedion v. vitreum (Mitchill), from Saginaw Bay, November 1942, May 1943, and April 1944. Inst. Fish. Res., Michigan Dept. Cons., Rep. No. 973, 5 pp.
Review of series of filleting experiments that served as basis of present Michigan minimum legal weight of 9 ounces for walleye fillets.

Lennon, Robert E.
1954. Feeding mechanism of the sea lamprey and its effect on host fishes. Fish. Bull., Fish and Wildlife Serv., Vol. 56, pp. 247-293.
Attachment to the fish and penetration of the fish's body by the sea lamprey are furthered by the suctorial, tooth-lined mouth and the rasping tongue. Feeding is assisted by secretions from the buccal glands which are potent anticoagulants and have a marked hemolytic and cytolytic action. Most victims die of hemorrhage; the erythrocyte count of dying fish is reduced 84 percent. Survivors of lamprey attacks often die of fungus infection of the wound. Data are given on the relative frequency of wounds on different parts of the fish's body and the gross pathology is described for wounds in different locations.

1955. Artificial propagation of the sea lamprey, Petromyzon marinus. Copeia 1955, No. 3, pp. 235-236.
An account of the stripping, fertilization, hatching (10 to 16 days at 67° - 71° F), early development, growth and behavior. Observations were concluded at the end of 21 weeks.

Loeb, Howard A.
1953. Sea lamprey spawning: Wisconsin and Minnesota streams of Lake Superior. Fish and Wildlife Serv., Spec. Sci. Rep.--Fish. No. 97, 36 pp.
Report on the examination of all tributaries in Minnesota, part of the streams of Wisconsin, and the streams of Grand Island. Streams are classified as to their "lamprey potential" on the basis of spawning facilities, larval habitat, and presence of natural or man-made barriers to migration.

Loeb, Howard A., and Albert E. Hall, Jr.
1952. Sea lamprey spawning: Michigan streams of Lake Superior. Fish and Wildlife Serv., Spec. Sci. Rep.--Fish. No. 70, 68 pp.
Results of surveys of 869 streams in 1950 and 178 in 1951 (both figures inclusive of tributaries) to ascertain occurrence of sea lamprey spawning runs and to estimate productive potentials of streams on basis of extent of spawning grounds and larval habitat. Tentative outline is given of control program (based principally on electrical devices and barrier dams) for the 194 streams on which control ultimately may prove necessary.

McLain, Alberton L.
1952. Diseases and parasites of the sea lamprey, Petromyzon marinus, in the Lake Huron basin. Trans. Am. Fish. Soc., Vol. 81 (1951), pp. 94-100.
Results of examination of 215 recently transformed young, 29 active feeders from the lake, and 257 sexually mature upstream migrants. Evidence of disease was small. Percentages of parasitic infestation were: recently transformed young--2.3; lake feeders--31.0; sexually mature lampreys--14.8. Young lampreys harbored nematodes only; last two groups carried acanthocephalans, nematodes, and cestodes.

Parasites are considered unimportant as a natural control of the lamprey.

1957. The control of the upstream movement of fish with pulsated direct current. Trans. Am. Fish. Soc., Vol. 86 (1956), pp. 269-284.
Alternating-current barriers placed in streams to block spawning runs of sea lampreys in some situations cause heavy mortalities of useful fish. To reduce this loss a direct-current diversion device is placed downstream. This equipment is described and the circuitry is illustrated. Most significant feature is the introduction of the negative field into the stream. Fish are turned away from the alternating-current field and diverted into a trap. Two devices tested over an entire season gave excellent results.

McLain, Alberton L., and Willis L. Nielsen
1953. Directing the movement of fish with electricity. Fish and Wildlife Serv., Spec. Sci. Rep.--Fish. No. 93, 24 pp.
Description of equipment, procedure, and results in laboratory and field experiments (mostly with brook trout, rainbow trout, and white suckers). Best results were obtained with square wave shape at a duty cycle of 0.66, frequency of 3 per second. Variation of reaction according to size of fish was a major difficulty. Technical problems are reviewed and recommendations made for further research.

Moffett, James W.
1950. Progress report on the sea lamprey program. The Fisherman, Vol.18, No. 7, pp. 5 and 8.
Outline of organization of the expanded Great Lakes Fishery Investigations, account of works in progress, and statement of proposed researches on the development of methods of controlling the sea lamprey.

1950. Sea lamprey control. Mich. Cons., Vol. 19, No. 4, pp. 18-20.
Popular review of the subject emphasizing the use of known facts in the life history of the sea lamprey in the technical problem of developing methods of control by mechanical barriers, electricity, poisons, and other means.

1952. The study and interpretation of fish scales. The Science Counselor, Vol. 15, No. 2, pp. 40-42.
Popular account touching such points as: structure of scales; development of the use of scales and bones for growth studies; preparation and microscopic examination of scales and scale impressions; practical applications of growth data.

1953. Report of Committee on Hydrobiology and Fish Culture. Trans. Am. Fish. Soc., Vol. 82 (1952), pp. 315-320.
Major impediments to effective research include: a poor "research climate", inherent in our very culture; superficiality of training; a mania for action programs which demand quick results, and give no opportunity for mature consideration: diversion of best researchers into administration. Suggestions are given for the correction of these evils.

1953. Lake fisheries need lamprey control and research. The Fisherman, Vol. 21, No. 4, pp. 10-11 and 14.
The invasion of the sea lamprey, its destruction of lake trout in Lakes Huron and Michigan, and its threat to Lake Superior are reviewed. Control of lampreys is imperative if fisheries are to be spared in Lake Superior and restored in Huron and Michigan. Yet, control is not enough. We must have a greatly expanded and continuing research program to learn the factors of abundance of fish. Certain specific research problems are listed.

1953. War on lampreys. The Philadelphia Enquirer, Aug. 23.
Popular account of the invasion of the sea lamprey, its threat to the fisheries, and steps taken to meet that threat.

1954. Fisheries knowledge increased through research vessel. The Fisherman, Vol. 22, No. 3, pp.7 and 13-14.

Description of the vessel Cisco, with photograph, deck plans, and sectional sketch; listing of equipment and gear for navigation and for fishery, limnological, and hydrographic research; discussion of types of research made possible by the vessel and of practical contributions to fishery knowledge and management.

1954. Killers of the Great Lakes. The Book of Knowledge Annual, 1954, pp. 125-127.

Popular, illustrated story of the sea lamprey, its damage to the fishery, and research aimed at the development of effective control.

1954. A research program for Lake Erie. The Fisherman, Vol. 22, No. 1, pp. 7, 11-12, and 14.

Detailed suggestions are offered for research along four major lines: identities, distribution, and movements of stocks; fluctuations of catch and availability in relation to year-class strength, size at capture, and rate of exploitation; factors of abundance; experimental management.

1956. Status of sea lamprey control. Wis. Cons. Bull., Vol. 21, No. 4, pp. 14-17.

Up-to-date statement of progress, extent, and methods of current control program; plans for expansion are outlined and possible alternative use of chemicals is discussed.

1956. The lake trout endangered in the Great Lakes. In: Our Endangered Wildlife, Nat. Wildlife Fed., pp. 23-24.

Review of effects of sea lamprey predation which has brought the lake trout to near extinction in Lakes Huron and Michigan and warning of impending collapse in Lake Superior if lamprey control is not achieved soon.

1955. Fisheries of the Great Lakes. In: The Great Lakes and Michigan. Great Lakes Res. Inst., Univ.Mich., pp. 36-37.

Includes brief comments on: the limits of research of earlier years; expansion of studies in the face of the sea lamprey crisis; present research program on the lamprey, and on limnology and fisheries; the outlook for future research.

1956. Great Lakes Fishery Commission: role of the Commission in the solution of fishery problems. In: Great Lakes--Programs and Problems, Great Lakes Comm., pp. 14-16.

Describes the origin and organization of the Commission; lists its principal duties as (1) the development and implementation of programs for research on and control of the sea lamprey and (2) coordination of fishery research on the Great Lakes; reviews early activities of the Commission and its Scientific Advisory Committee.

1957 Recent changes in the deep-water fish populations of Lake Michigan. Trans. Am. Fish. Soc., Vol. 86 (1956), pp. 393-408.

The invasion of the sea lamprey precipitated a series of sweeping changes that are still in progress. First came the destruction of stocks of lake trout and burbot, and with it an end of predation by these fish on smaller species, principally the bloater (a chub) and cottids. At the same time lampreys were forced to turn to the larger species and individuals of ciscoes or chubs as food. As a result, bloaters (and presumably cottids also) increased in abundance and larger chubs grew scarce. By 1954-55 the abundance of bloaters was 347 percent but that of large chubs (10 inches or longer) only 37 percent of that in 1930-32 when an earlier survey was made.

Mraz, Donald
1952. Movements of yellow perch marked in southern Green Bay, Lake Michigan, in 1950. Trans. Am. Fish. Soc., Vol. 81 (1951), pp. 150-161.
Analysis of data on recoveries in the commercial fishery of 108 of 4,172 spawning yellow perch marked in southern Green Bay in May 1950 by strap tags attached to the operculum. Recoveries indicated progressive northward movement following spawning. Fish recaptured outside the marking area averaged significantly longer than those recaptured locally. Rise of percentage return with increase in size suggested greater ability of larger fish to survive tagging or to retain tags. Marking by fin-clipping proved unproductive.

Parker, Phillip S., and Robert E. Lennon
1956. Biology of the sea lamprey in its parasitic phase. Fish and Wildlife Serv., Res. Rep. No. 44, 32 pp.
Sea lampreys reared in aquaria through the parasitic phase grew less rapidly than wild lampreys but nevertheless attained maturity. Females made more attacks, fed more, killed more fish, and grew larger than did males. Average destruction of fish per lamprey was 18.5 pounds; in nature, this figure may be twice as great. Few fish survived lamprey attacks and most survivors later died of secondary infections.

Perlmutter, Alfred
1951. An aquarium experiment on the American eel as a predator on larval lampreys. Copeia, 1951, No. 2, pp. 173-174.
A controlled experiment which proved that eels located and destroyed larval lampreys in the bottom mud of an aquarium. Importation of eels is suggested as a possible method of biological control of the sea lamprey in the upper Great Lakes.

Pycha, Richard L., and Lloyd L. Smith, Jr.
1955. Early Life history of the yellow perch, Perca flavescens (Mitchill), in the Red Lakes, Minnesota. Trans. Am. Fish. Soc., Vol. 84 (1954), pp. 249-260.
A study of the life history during the first year of life with particular reference to: scale formation;body-scale relation; timing and variability of growth; length-weight relation; food habits in relation to growth and survival.

Smith, Bernard R., and Oliver R. Elliott
1953. Movement of parasitic-phase sea lampreys in Lakes Huron and Michigan. Trans. Am. Fish. Soc., Vol. 82 (1952), pp. 123-128.
Recoveries from 219 parasitic-phase sea lampreys tagged in northwestern Lake Huron totalled 38 or 17.7 percent. One was recaptured in northeastern Lake Michigan and the remaining 37 in Lake Huron. Movement was generally southward; 5 individuals had travelled more than 150 miles, 4 of them to Canadian waters of southern Lake Huron.

Smith, Lloyd L., Jr., and Laurits W. Krefting
1954. Fluctuations in production and abundance of commercial species in the Red Lakes, Minnesota, with special reference to changes in the walleye population. Trans. Am. Fish. Soc., Vol. 83 (1953), pp. 131-160.
An analysis of production statistics, 1917-1953, and of records of catch, effort, and abundance, 1930-1953, with special respect to the principal commercial species, walleye and yellow perch. Changes of walleye abundance are independent of fishing pressure but traceable to fluctuations of year-class strength. Year-class strength could not be correlated with abundance of brood fish, abundance of competing species, hatchery plantings, or weather conditions. Provision for prediction of abundance and flexible regulations is recommended.

Smith, Oliver H., and John Van Oosten
1940. Tagging experiments with lake trout, whitefish, and other species of fish from Lake Michigan. Trans. Am. Fish. Soc., Vol. 69 (1939), pp. 63-84.
Analysis of data on recoveries of 388 or 13.4 percent of 2,902 fish (nearly half of them lake trout) tagged at Port Washington, Wisconsin, to establish patterns of movement of lake trout, whitefish, lake herring, yellow perch, rainbow trout, sturgeon, and other species. Recaptures of lake trout were at first local but within 3 years were fairly well scattered throughout the lake. Movements of other fishes varied from species to species. Data are included on the growth of tagged lake trout, rainbow trout, whitefish, and sturgeon.

Smith, Stanford H.
1954. Method of producing plastic impressions of fish scales without using heat. Prog. Fish.-Cult., Vol. 16, No. 2, pp. 75-78.
Principal features of the roller-press described are: large, 3-inch rollers that apply the pressure over a relatively wide area; micrometer adjustment for the control of the spacing between rollers; reduction gear to permit slow passage of the plastic strip between the rollers. Detailed instructions are given for the use of the equipment.

1956. Research vessel Cisco operations in 1955. Comm. Fish. Rev. Vol. 18, No. 5, pp. 21-23.
Brief statement of the research program in northern Lake Michigan on the abundance, distribution, and natural history of chubs, and on the limnology (hydrography, plankton, bottom organisms).

1956. Life history of lake herring of Green Bay, Lake Michigan. Fish. Bull., Fish and Wildlife Serv., Vol. 57, pp. 87-138.
A general inquiry including data on: production and commercial importance; size, age, and growth; year-class strength; length-weight relation; distribution and movements; sex ratio, maturity, fecundity, spawning season and grounds. Discusses in detail the problem of "growth compensation" and the biasing effects of selective fishing on samples of the stock.

1957. Limnological surveys of the Great Lakes--early and recent. Trans. Am. Fish. Soc., Vol. 86 (1956), pp. 409-418.
Reviews first the early explorations and casual observations and the initial limnological studies--useful but scattered and small-scale. The most effective surveys have been possible through inter-agency cooperation which permits a pooling of facilities, staff, and equipment. Expansion of limnological research on the Great Lakes has been rapid in late years, and the outlook for the future is good.

Van Oosten, John
1923. A study of the scales of whitefishes of known ages. Zoologica, Vol. 2, No. 17, pp. 380-412.
Study of scale structure of whitefishes reared artificially in the New York Aquarium, demonstrating conclusively the validity of the annulus as a year mark. Includes data on body-scale relationship and evidence that temperature is a primary factor in annulus formation.

1928. Fisheries of the Great Lakes. Life histories of the Coregoninae. In: Progress in biological inquiries, 1926, by Elmer Higgins. Rep. U.S. Comm. Fish. for 1927, pp. 662-667.
Comments on validity of scale method (with emphasis on the nature of Lee's phenomenon) and progress report on life-history study of lake herring of Saginaw Bay.

Van Oosten, John

1928. Scientific investigations of Great Lakes fisheries by the U. S. Bureau of Fisheries. Second Great Lakes Fish. Conf., Lansing, Mich., Feb. 8, 1928, Mich. Dept. Cons., pp. 16-20.

Outline of controversial problems of regulation in Lake Erie and description of the Service's experimental studies of net selectivity intended to contribute toward the solution of those problems.

1929. Some fisheries problems on the Great Lakes. Trans. Am. Fish. Soc., Vol. 59, pp. 63-85.

Outline of problems and presentation of preliminary data on: effects of set-hook fishing on stocks of lake trout and of chubs used for bait; regulation of chub nets for protection of both chubs and small lake trout; protection of Saginaw Bay lake herring; biological and limnological studies; cooperative survey of Lake Erie.

1929. Life history of the lake herring (Leucichthys artedi Le Sueur) of Lake Huron as revealed by its scales, with a critique of the scale method. Bull. U. S. Bur. Fish., Vol. 44, pp. 265-428.

An inquiry into the validity of the scale method and an application of that method in a study of the life history of the lake herring (principally the Saginaw Bay stock) of Lake Huron. Critique includes an exhaustive review and evaluation of the literature and an appraisal of the author's own findings on such fundamental questions as: validity of the annulus as a year-mark; time and factors of annulus formation; body-scale relationship and calculation of growth; possible causes of Lee's pheonomenon and other discrepancies of calculated growth. Life-history study includes consideration of: fluctuations in age composition, size, and growth of the Saginaw Bay lake herring and possible contributing factors; growth compensation; length-weight relationship; sex ratio; differences between growth of lake herring in Saginaw Bay and in other regions of Lake Huron.

1930. Progress of fishery biology on the Great Lakes. In: Progress in biological inquiries, 1928, by Elmer Higgins. Rep. U.S. Comm. Fish. for 1929, pp. 710-718.

Historical review of major limnological, biological, and fishery surveys of the Great Lakes by governmental agencies and educational institutions. Includes an outline of the Service research program and comments on problems of overfishing and fishery regulations.

1930. Investigation of method of measuring twine in Great Lakes district. Mich. Fisherman, Vol. 14, No. 4, pp. 1 and 6.

Review of troublesome points in the controversial problem of measuring mesh size, emphasizing the need for a simple uniform procedure free from personal bias and stating that the Service has referred the matter to the Bureau of Standards.

1930. The disappearance of the Lake Erie cisco--a preliminary report. Trans. Am. Fish. Soc., Vol. 60, pp. 204-214.

Review of production statistics on the cisco fishery and explanation of the collapse of the fishery in 1925 as the result of overfishing with bull nets (deep gill nets) in 1923 and 1924 when abnormal weather conditions (heavy storms) had concentrated the stocks within a small area of deep water in eastern Lake Erie.

1932. Experiments on the mesh of trapnets and legislation of the commercial fisheries of Lake Erie. Trans. Am. Fish. Soc., Vol. 62, pp. 100-107.

Description of experimental design and presentation of selected data to

show type of results from studies of relation of mesh size to release of undersized fish and catch of legal-sized fish of several species. Recommendations are given on legal specifications for trap-net meshes.

1932. Experiments on the mesh of trap-nets on Lake Erie. The Fisherman, Vol. 1, No. 12, pp. 3-4 and 8.
Summary of article published under similar title in same year in Transactions of the American Fisheries Society.

1932. Review of Great Lakes work conducted by the U. S. Bureau of Fisheries. The Fisherman, Vol.2, No. 1, pp. 3-4 and 8.
Review of 1927-1932 activities with emphasis on the practical nature of the program and with particular reference to fishery and limnological studies on Lake Erie, experimental chub-net fishing on Lake Michigan, and research on the deep trap net in Lakes Huron and Michigan.

1932. The maximum age of fresh-water fishes. The Fisherman, Vol. 1, No. 11, pp. 3-4.
List of maximum ages, from artificial rearing or examination of scales or other bony structures, for 44 species, drawn from the literature or based on studies by Great Lakes staff.

1933. Recent developments in commercial fishing industry. (Report of the Division of Commercial Fishing of the American Fisheries Society) Trans. Am. Fish. Soc., Vol. 63, pp. 31-35.
Review of developments, with special reference to the Great Lakes, in such matters as regulations and technical advances in gear, boats, processing, transportation, marketing, and the collection and analysis of statistics.

1933. Preliminary report on investigation of chubnet meshes in Lake Michigan. The Fisherman, Vol. 2, No.4, pp.3-4 and 8.
Condensed summary of numbers and pounds of lake trout and chubs per lift of chub gill nets of different mesh size in different regions of lake. Abundance of chubs and small trout on Michigan side of lake, 2.7 times that in Wisconsin, was attributed to use of larger meshes in Michigan nets. Uniform adoption of 2-3/4-inch mesh was recommended.

1934. On the deep trap net in the State of Michigan. Mich. Tradesman, Vol. 52, No. 2674, p. 25. (A letter).
Review of the development of the deep-trap-net fishery showing from statistical records the dangerous increase of production of whitefish resulting from the use of the gear and the disastrous depletion of grounds fished intensively by deep trap nets. Advocates specific restrictive regulations.

1934. The value of questionnaires in commercial fisheries regulations and surveys. Trans. Am. Fish. Soc., Vol. 64, pp. 107-117.
Recommendations of the questionnaire as a cheap and efficient means of obtaining biological and statistical data on fish and fisheries and of learning the views of the industry on questions of management and regulation. Includes examples to demonstrate the reliability and usefulness of data from questionnaires.

1935. Questionnaires prove valuable to fisheries. The Fisherman, Vol. 4, No. 6, pp. 1-2; Vol. 4, No. 7, pp. 1-2.
Summary of article with similar title published in 1934 in the Transactions of the American Fisheries Society.

1935. Logically justified deductions concerning the Great Lakes fisheries exploded by scientific research. Trans. Am. Fish. Soc., Vol. 65, pp. 71-75.
Presentation of data to prove that logically based assumptions and popularly held beliefs are incorrect with respect to the relationship between mesh size

and the size and number of fish taken, the relationship between fishing time and the catch of stationary gear, and the role of pollution in the decline of fish stocks in the Great Lakes.

1935. Lake states change fishery regulations. The Fisherman, Vol. 4, No. 10, pp. 1-2.
Review of changes of commercial fishery regulations enacted by States of Michigan, Indiana, and Wisconsin.

1935. First record of the alewife, Pomolobus pseudoharengus, for the State of Michigan. Copeia, 1935, No. 4, pp. 194-195.
Report of capture of alewife in northern Lake Huron off Rogers City, Michigan--first record for the State and second for the lake. Belief is expressed that the alewife reached Lake Huron from Lake Ontario by way of the Trent waterway and Georgian Bay.

1936. A new immigrant comes to Michigan. The Fisherman, Vol. 5, No. 6, pp. 1 and 3.
Statement of first Michigan record of alewife, reported in 1935 article in Copeia.

1936. Dr. Van Oosten reveals startling data. Gold Medal Netting News, Vol. 9, May 1936, pp. 1-2.
A discussion of mesh selectivity stressing that the numbers and sizes of fish taken in nets of a particular mesh size are not to be deduced on mechanical grounds but must be determined from experimentation.

1936. Net selectivity on the Great Lakes. Gold Medal Netting News, Vol. 10, July 1936, pp. 2-3.
Continuation of article in May 1936 issue of same journal, introducing data on relation of mesh size to: catches of small trout and chubs in gill nets in Lake Michigan; release of under-sized fish from shallow trap nets in Lake Erie; release of small whitefish from deep trap nets in Lakes Huron and Michigan.

1936. The mortality of fish in Lake Erie. Great Lakes Fisherman, Vol. 1, No. 3, pp. 2 and 10; Vol. 1, No. 4, pp. 2-3. (Also in: Combined Biennial Rep., 1938, Pa. Bd. Fish. Comm.)
Analysis of the species composition of fish found dead on beaches of the south shore of Lake Erie and a consideration of the several factors that may have contributed to the mortality. Destruction of undersized fish in the sorting of the catch of commercial gears and the dumping of legal-sized fish in poor condition are suggested as the most important factors.

1936. Lake fisheries facing extermination. The Fisherman, Vol. 5, No. 11, pp. 1 and 3.
Discussion of unique and valuable character of Great Lakes fisheries and illustration from statistics for selected species of downward trend in production. Decline was attributed to overfishing made possible by the apathetic attitudes of State legislatures. (Article based on talk given over NBC network.)

1937. Doom of the Great Lakes fisheries. Am. Forests, Vol. 43, pp. 103-105 and 144-145.
A plea for central control of the Great Lakes fisheries, held essential to bring about the restrictions on fishing intensity necessary to put an end to the progressive depletion of the stocks of fish.

1937. First records of the smelt, Osmerus mordax, in Lake Erie. Copeia, 1937, No. 1, pp. 64-65.
Record of first smelt identified from Lake Erie, captured off Vermilion, Ohio, June 30, 1936, and review of several earlier and later reports of smelt indicating firm establishment of the species in the lake.

Van Oosten, John

1937. The Great Lakes fisheries: their proper management for sustained yields. Trans. Am. Fish. Soc., Vol. 66, (1936), pp. 131-138.

Recommendation of seven-point program of regulation and research: centralized control and discretionary power; complete statistics properly analyzed; research on causes of fluctuations in abundance and yield; identification of races and studies of migrations; experimental investigations of gear; evaluation of artificial and natural propagation; control over introductions of exotic species.

1937. The dispersal of smelt, Osmerus mordax (Mitchill), in the Great Lakes region. Trans. Am. Fish. Soc., Vol. 66 (1936), pp. 160-171.

Record of plantings of smelt in the Great Lakes and a year-by-year account of the spread of the smelt through Lakes Michigan, Huron, Superior, and Erie.

1937. The North Central States Wildlife Conference. The Prog. Fish.-Cult., Bur. Fish. Memo. 1-131, No. 26, pp. 15-19.

Review and evaluation of papers and discussions at the conference on such questions as: methods and values of surveys; fish populations of "type" waters and limitations of the type-water concept; effectiveness of artificial propagation and environmental improvement.

1937. The age, growth, and sex ratio of the Lake Superior longjaw, Leucichthys zenithicus (Jordan and Evermann). Pap. Mich. Acad. Sci., Arts, and Lett., Vol. 22 (1936), pp. 691-711.

Life-history study giving data on age and size distribution, growth in length and weight, growth compensation, sex ratio, length-weight relationship, and condition (a negative correlation demonstrated between the growth rate and condition of individual fish). Protection of longjaw to end of sixth year of life (total length, about 10.3 inches) is advocated.

1937. Artificial propagation of commercial fish of the Great Lakes. Trans. 2nd N. Am. Wildlife Conf., pp. 605-612. (Reprinted with slight changes of title and text in The Progressive Fish-Culturist, Bur. Fish. Memo. 1-131, No. 28, 1937).

General discussion of the subject, with emphasis on the facts that correlations have not been found between fry plantings and the later take of fish and that fish-culturists have underestimated the effectiveness of natural reproduction and also have failed to consider the true loss of eggs to the lake (killing of green fish, inefficient stripping, ···) attendant on artificial propagation.

1938. Michigan's commercial fisheries of the Great Lakes. Mich. Hist. Mag., Vol. 22, pp. 3-39.

Review of fishery from earliest to modern times with respect to fishing grounds, boats and gear (construction and operation of different types described), and trends of production. Includes accounts of early statistical and biological surveys and of modern research programs and an analysis of present-day problems of regulation and management.

1938. The extent of the depletion of the Great Lakes fisheries. Proc. Great Lakes Fish. Conf., at Detroit, Mich., Feb. 25-26, Council of State Governments, pp. 10-17.

Presentation and discussion of charts showing outstanding examples of collapse in production in Lake Erie sturgeon, Lake Superior whitefish, Lake Huron yellow perch, ···. Stresses fallacy of use of total production figures that do not reflect progressive shift of species composition from more valuable to coarse varieties or show effects of exploitation of new grounds or varieties (as in the recently expanded lake herring fishery of Lake Superior).

Van Oosten, John

1938. The age and growth of the Lake Erie sheepshead, Aplodinotus grunniens Rafinesque. Pap. Mich. Acad. Sci., Art, and Lett., Vol. 23 (1937), pp. 651-668.

Life-history study including data on age and size composition, growth in length and weight, growth compensation, length-weight relationship, and condition. The large size attained by some sheepshead was shown to depend on a long life.

1938. From cisco to perch to pike. State Government, Vol. 11, pp. 55-57.

Review of decline of production of selected species in certain lakes with emphasis on the progressive nature of depletion in the Great Lakes, shown especially by deterioration of average quality of the catch as fishermen turned to cheaper species after depleting the stocks of the more desirable varieties.

1939. A common concern···Great Lakes fisheries for anglers and fishers. Mich. Game Trails, Vol. 1, No. 5, pp. 1-2.

A plea for greater interest and assistance from sportsmen and the general public to put an end to the inadequate and divided control responsible for the depletion of Great Lakes fisheries (illustrated by selected examples of decline of production from earlier "normals").

1939. Save the Great Lakes fisheries'. Outdoor Am., Vol. 4, No. 3, pp. 4-5 and 7.

A call for public support of attempts to obtain immediately discretionary power for conservation departments, and ultimately international control of the Great Lakes fisheries. Such moves were held to offer the only means to obtain the drastic measures needed to save the fisheries.

1939. Battle rages over closing Potagannissing Bay to commercial fishermen. Mich. Game Trails, Vol. 1, No. 3, pp. 19-20.

Review and summary of 1939 report by Westerman and Van Oosten on the Potagannissing Bay problem.

1939. The age, growth, sexual maturity, and sex ratio of the common whitefish, Coregonus clupeaformis (Mitchill), of Lake Huron. Pap. Mich. Acad. Sci., Arts, and Lett., Vol. 24, Pt. 2, (1938), pp. 195-221.

General life-history study of whitefish from Alpena, Michigan, area of Lake Huron including data on age composition (III-XII represented, IV-VII most plentiful), size distribution, growth rate, length-weight relationship and condition, sex ratio (about 50:50 but males scarce at higher ages), and maturity (size limit of 22 inches necessary to give immature females full protection).

1939. Can the Great Lakes fisheries be saved? Am. Wildlife, Vol. 28, No. 3, pp. 129-135.

Alarming account of the commercial extinction of valuable species in past years and of the current rapid depletion of still others, followed by a review of the failure of all attempts to obtain adequate regulations through interstate cooperation and an urgent appeal for support of international control of the Great Lakes fisheries.

1940. The smelt, Osmerus mordax (Mitchill). Mich. Dept. Cons., 13 pp.

Popular account of the natural history of the smelt--habitat, spawning, growth, food, predators, ····-, its introduction and spread in the Great Lakes, and its possible future importance as a food and sport fish and as a competitor with and predator on native species.

1941. The age and growth of fresh-water fishes. In: A Symposium on Hydrobiology, Univ. of Wis. Press, pp. 196-205.

An appeal for further and more discriminating research into fundamental aspects of the scale method, a review of recent developments in the use of scale measurements for the calculation of past growth, and an outline of the numerous applications of age-and-growth studies in conservation and fish management and in taxonomic investigations.

1942. The age and growth of the Lake Erie white bass, Lepibema chrysops (Rafinesque). Pap. Mich. Acad. Sci., Arts, and Lett., Vol. 27 (1941), pp. 307-334.
Life-history study including data on body-scale relationship, age composition (less than 5 percent over 3 years old), size composition (62 percent below legal length of 9 inches), growth in length and weight, growth compensations, length-weight relationship, condition, and age and size at maturity.

1942. Relationship between the plantings of fry and production of whitefish in Lake Erie. Trans. Am. Fish. Soc., Vol. 71 (1941), pp. 118-121.
Study of correlation between whitefish fry plantings in Lake Erie and the later commercial production of whitefish. No evidence was found of benefits from plantings.

1942. The Great Lakes whitefish. In: Fading Trails, The Macmillan Co., pp. 216-222.
Review of life history and habits of whitefish, account of depletion of Lake Huron whitefish by the deep trap net, and general discussion of the problem of depletion in the Great Lakes with strong appeal for support of uniform regulations and central control.

1942. The Great Lakes fisheries: a review of the report of the International Board of Inquiry for the Great Lakes Fisheries. State Government, Vol. 15, pp. 211-212 and 219-220.
History of events leading to the appointment of the International Board of Inquiry for the Great Lakes fisheries, a description of the Board's activities, and a digest of the report of the full board and of the supplemental report of the U. S. members.

1943. U. S.-Canadian control urged to conserve Lake Erie fish supply. The Clevelander, Vol. 17, No. 10, pp. 9-10 and 24.
Account of depletion in Lake Erie as illustrated by declining production of various species, discussion of need for adequate uniform regulations and of impossibility of attaining them under state control of the fisheries, and conclusion that international control is only means of preventing collapse of the fishing industry.

1944. The great smelt mystery. Mich. Cons., Vol. 13, No. 6, p. 8.
Comparison of smelt production before and after the 1942-1943 mortality, record of certain small post-mortality spawning runs, and statement that epidemic disease provided the only acceptable explanation of the mortality.

1944. Factors affecting the growth of fish. Trans. 9th N. Am. Wildlife Conf., pp. 177-183.
Review of literature and appraisal of present status of knowledge of factors of growth (both fluctuations within stocks and differences between stocks) in natural waters. Includes consideration of food (natural production and food competition), space factor, temperature, and precipitation. Stresses need for better understanding of factors of growth as essential to sound management.

1946. Maximum size and age of whitefish. The Fisherman, Vol. 14, No. 8, pp. 17-18.
Presentation of records of age and size (length and/or weight) for nine whitefish (seven from the Great Lakes and one each from Lake Nipigon and Lake Champlain) from 15 to 22 or 23 years old. Old whitefish are smaller in water not fished commercially than in commercially exploited areas.

Van Oosten, John

1947. Mortality of smelt, Osmerus mordax (Mitchill), in Lakes Huron and Michigan during the fall and winter of 1942-1943. Trans. Am. Fish. Soc., Vol. 74 (1944), pp. 310-337.

Description of the spread of the mortality, evaluation of the many suggested causes (bacterial or virus disease held to offer the only explanation consistent with the facts), estimate of loss of production to commercial and sport fishermen, demonstration of improved growth of smelt following the mortality, and discussion of prospects for the recovery of smelt stocks.

1948. Turbidity as a factor in the decline of Great Lakes fishes with special reference to Lake Erie. Trans. Am. Fish. Soc., Vol. 75, (1945), pp. 281-322.

Exhaustive treatment of the controversial question as to whether increase of turbidity due to improper land use or improper fishing has caused the decline of the Lake Erie fisheries. Review of literature on effects of turbidity on fish is followed by presentation of argument in support of conclusions: beach erosion and wind action rather than cropland erosion are principal sources of turbidity in Lake Erie; levels of turbidity are generally too low to affect fish adversely; trends in turbidity since 1910-1915 have been downward, not upward as many have believed; fluctuations of turbidity have shown no correlation with fluctuations of growth and strength of year classes; restoration of the fisheries must come through scientific fishery management--not scientific farming.

1949. The present status of the United States commercial fisheries of the Great Lakes. Trans. 14th N. Am. Wildlife Conf., pp. 319-330.

Discussion of depletion as exemplified by declining production in the face of more intensive and efficient fishing. Demonstrates from comparison of 1879-1903 and 1936-1945 statistics that total U. S. yield would have decreased much more but for a large rise in the take of coarse fish. Includes data on the decline in production of important species in individual lakes.

1949. The sea lamprey--a threat to Great Lakes fisheries. State Government, Vol. 22, pp. 283-284, and 289.

History of penetration and spread of the sea lamprey in the upper Great Lakes, records of losses of production of lake trout from lamprey depredations in Lakes Huron and Michigan, comments on the lamprey as a threat to the Lake Superior lake trout and to other species in all three lakes, and outline of current and proposed sea lamprey research.

1949. A definition of depletion of fish stocks. Trans. Am. Fish. Soc., Vol. 76 (1946), pp. 283-289.

A listing of situations not to be held as synonymous with depletion followed by the definition: "...reduction, through overfishing, in the level of abundance of the exploitable segment of a stock that prevents the realization of the maximum productive capacity."

1949. Progress report on the sea lamprey study. The Fisherman, Vol. 17, No. 3, pp. 6, 9, and 10.

Outline of program and statement of progress of cooperative researches of the Great Lakes Sea Lamprey Committee composed of representatives of the eight lake states, the Province of Ontario, and the Fish and Wildlife Service.

1950. Progress report on the study of Great Lakes trout. The Fisherman, Vol. 18, No. 5, pp. 5 and 8-10, and No. 6, pp. 5 and 8.

Outline of program of Great Lakes Lake Trout Committee (composed of representatives of states bordering the three upper lakes, the Province of Ontario, and the Fish and Wildlife Service) and report on results of plantings of about 400,000 fin-clipped

fingerlings in northern Lake Michigan in 1944-1946. Includes analysis of the data on the approximately 1,200 recoveries made through 1949 with respect to movement from planting locality, time out before recapture, growth, ···. Presents also information on similar but smaller scale experiments in Lakes Huron and Superior, and on growth in Lake Michigan as determined from scale studies of samples from the commercial catch.

1953. A modification in the technique of computing average lengths from the scales of fishes. Prog. Fish.-Cult., Vol. 15, No. 2, pp. 85 86.

A demonstration that: estimates of the length of fish at the end of different years of life based on average scale measurements differ insignificantly from the averages of the calculated lengths of individual fish; the use of total lengths in growth calculations yields essentially the same results as are obtained when standard lengths are calculated and subsequently converted to total lengths.

1956. The skin and scales. In: The physiology of fishes. Vol. 1. Metabolism. (M. E. Brown, Ed.), Academic Press, pp. 207-244.

The structure, chemical composition, and functions of the skin of fishes and of various types of scales (cosmoid, ganoid, placoid, cycloid, and ctenoid) are described. Sections are included on: the variability in squamation; structures formed by the modification of scales and their function; use of scales in classification and life-history studies.

1956. Lake sturgeon. In: Our Endangered Wildlife, Nat. Wildlife Fed., pp. 9-10.

Slow growth (large fish may be 150 years old or older) and late maturity (first spawning at about 20 years) made the sturgeon highly susceptible in the Great Lakes to the deliberate destruction of the early years, the later overfishing, and more recently to adverse changes of the environment. Great Lakes stocks are so reduced that extinction is threatened in some areas. Problems of restoration are difficult.

Van Oosten, John, and Hilary J. Deason

1938. The food of the lake trout (Cristivomer namaycush namaycush) and of the lawyer (Lota maculosa) of Lake Michigan. Trans. Am. Fish. Soc., Vol. 67 (1937), pp. 155-177.

Analysis of stomach contents showing frequency of occurrence and estimated volume of various food items for the two species according to size of fish and region of the lake (southern, northern, and Green Bay). Lake trout and lawyers (burbot) were found to be competitors for food and both were predators on commercially valuable coregonids. Competition was indicated also between lawyers and coregonids for invertebrate foods.

1939. The age, growth, and feeding habits of the whitefish, Coregonus clupeaformis (Mitchill), of Lake Champlain. Trans. Am. Fish. Soc., Vol. 68 (1938), pp. 152-162.

Comparison of samples from northern and southern areas of the lake. The two areas were held to possess distinct populations because of separate spawning grounds and differences in size and age composition, growth rate, and condition. Invertebrates made up 99.1 percent of the food in stomachs of southern Lake Champlain whitefish; molluscs (principally amnicolids) accounted for 92.8 percent of the total food.

1957. History of the Red Lakes fishery, 1917-1938, with observations on population status. Fish and Wildlife Serv., Spec. Sci. Rep.--Fish. No. 229, pp. 1-63.

Historical account traces the development of the commercial fishery from its inception in 1917 through 1938.

Trends of production and catch-per-unit-effort are followed for principal species. Life history data are given for the walleye and yellow perch. Historical accounts are provided of the artificial propagation of the walleye and whitefish from 1918 through 1938.

Van Oosten, John, Hilary J. Deason, and Frank W. Jobes

1934. A microprojection machine designed for the study of fish scales. Jour. du Cons., Vol. 9, pp. 241-248.

Description, illustrated by cross-section drawing and photograph, of optical equipment and general structural specifications of machine specially adapted to scale work.

Van Oosten, John, and Paul H. Eschmeyer

1956. Biology of young lake trout (Salvelinus namaycush), in Lake Michigan. Fish and Wildlife Serv., Res. Rep. No. 42, 88 pp.

Based on collections of five mesh sizes (2-3/8 to 3 inches) of experimental gill nets fished in 1930-1932. Includes information on: annual and local variation of size, age, and growth; length-weight relation and condition; sex ratio; geographical and bathymetric distribution; local and regional differences and seasonal changes in abundance; selective action of gill nets; associated species of fish.

Van Oosten, John, and Ralph Hile

1949. Age and growth of the lake whitefish, Coregonus clupeaformis (Mitchill), in Lake Erie. Trans. Am. Fish. Soc., Vol. 77 (1947), pp. 178-249.

Analysis of production statistics, 1871-1946, to bring out long-term trends of yield and shifts in centers of production and a general life-history study including consideration of fluctuations in growth and the strength of year classes in relation to environmental condition, length-weight relationship (general relationship, seasonal changes of condition, loss of weight at spawning), variation of sex ratio with age and by season, age at maturity, and spawning season.

Van Oosten, John, Ralph Hile, and Frank W. Jobes

1946. The whitefish fishery of Lakes Huron and Michigan with special reference to the deep-trap-net fishery. Fish. Bull., Fish and Wildlife Serv., Vol. 50, pp. 297-394.

Review of statistics on production of whitefish in all waters of Lakes Michigan and Huron, beginning with 1879, and a detailed consideration of annual fluctuations of production, abundance, and fishing intensity in local districts of the State of Michigan waters of the two lakes, beginning with 1929, to bring out the disastrous effects of the deep trap net on whitefish stocks in those districts in which the gear was fished intensively. Includes sections on bathymetric distribution and seasonal movements of whitefish, lake trout, walleyes, burbot, and suckers, and on the fishing action of pound nets and deep trap nets (relation of mesh size to number and sizes of fish taken; gilling and bloating of live fish at lifting; numbers of dead fish in nets; estimates of total numbers of undersized fish destroyed).

Van Oosten, John, F. A. Westerman, W. C. Adams, and W. L. Finley

1939. Migratory fish, a problem of interstate cooperation? Trans. 4th N. Am. Wildlife Conf., pp. 25-43.

Panel discussion concerned principally with Great Lakes problems. Includes comments on the progressive depletion in the various lakes and the great difficulty of coping with the problem under the current system of divided control.

Westerman, Fred A., and John Van Oosten

1939. Report to the Michigan State Senate on the fisheries of Potagannissing Bay, Michigan. Mich. Dept. Cons., 82 pp.

Report on study conducted in response to pressure from sport fishermen for abolition of commercial fishing in the bay. Observations on the commercial fishery, tagging experiment on black bass, analysis of commercial fishery statistics, creel-census records, ...proved the contentions of sport fishermen concerning damage to angling from commercial operations to be invalid. Continuance of commercial fishing was recommended as desirable in this basically rough-fish water. Elimination of nets from one small area about 3 months each summer was the only change of regulation suggested.

Wigley, Roland, L.

1952. A method of marking larval lampreys. Copeia, 1952, No. 3, pp. 203-204.

Report on successful marking of larval lampreys as small as 30 millimeters long by subcutaneous injection of cadium sulfide, mercuric sulfide, and carbon. Marks had not faded after 1 to 1-1/2 years.

Willeford, B. R. Jr.

1956. The solubility of 3-bromo-4-nitrophenol in water and acetone. Ecology, Vol. 37, p. 840.

A study conducted to solve certain technical problems in the practical application of the compound to kill lamprey larvae in streams.

Wright, Stillman

1929. A preliminary report on growth of the rock bass, Ambloplites rupestris (Rafinesque), in two lakes of northern Wisconsin. Trans. Wis. Acad. Sci., Arts, and Lett., Vol. 24, pp. 581-595.

Brief report on length at capture and calculated growth in length of rock bass of best represented age groups in Muskellunge and Trout Lakes. Possibility of distinct populations with differing growth rates in the latter lake mentioned.

1932. Pollution in western Lake Erie. The Fisherman, Vol. 1, No. 6, pp. 3-4 and 10.

Review of researches emphasizing the fact that harmful effect of pollution near mouths of certain rivers was counterbalanced, at least in part, by benefits from nitrogen and other fertilizing elements in pollutants. It was stated that pollution could not explain the lowered productivity of the fisheries.

1932. Plankton and the fisheries. The Fisherman, Vol. 1, No. 7, pp.3-4 and 11.

Description of the principal organisms in plankton and the methods of plankton study and explanation of the significance of plankton in the production of fish.

1932. Conditions of life in lakes. The Fisherman, Vol. 1, No. 8, pp. 3-4 and 12.

Discussion of the lake as a habitat and of adaptations of fish to life in an aquatic environment.

1955. Limnological survey of western Lake Erie. Fish and Wildlife Serv., Spec. Sci. Rep.--Fish. No. 139, 341 pp. (Includes "The phytoplankton of western Lake Erie", by L.H. Tiffany; "The zooplankton of western Lake Erie", by Wilbur M. Tidd.)

Based principally on observations made in April-October 1929 and 1930, the report covers a limnological survey conducted with special reference to pollution. Extensive data are given on physical limnology, water chemistry, bottom fauna, phytoplankton, and zooplankton. Pollution was heavy in limited areas near the mouths of some rivers and was moderate in larger areas, but much of western Lake Erie was free of pollution. Because harmful effects of pollution were counterbalanced by beneficial effects of increased fertility, it was concluded that pollution was not a controlling factor in the welfare of the fisheries.

Wright, Stillman, and Wilbur M. Tidd
1933. Summary of limnological investigations in western Lake Erie in 1929 and 1930. Trans. Am. Fish. Soc., Vol. 63, pp. 271-285.
Report on 1929-1930 study of pollution situation in western Lake Erie as indicated by chemical analyses, phytoplankton, zooplankton, and bottom fauna. It was held that the harm from the heavy pollution of certain limited areas was in some measure counterbalanced by fertilizing effects of pollutants and that pollution probably was not the controlling factor in the production of fish in western Lake Erie.

PUBLICATIONS BY SCIENTISTS ASSOCIATED WITH GREAT LAKES FISHERY INVESTIGATIONS

The following list includes the principal publications of scientists not on the Great Lakes staff but whose research was based primarily on materials supplied by the Fish and Wildlife Service or was a part of a cooperative project to which the Service made a significant contribution in the collection of data or through the provision of facilities.

Ahlstrom, Elbert H.
1936. The deep-water plankton of Lake Michigan, exclusive of the Crustacea. Trans. Am. Micro. Soc., Vol. 55, pp. 286-299.
Results of analysis of plankton from vertical hauls of 1-foot cone-shaped net (No. 20 silk) made from the research vessel Fulmar. Gives species, lists, grouped in categories of relative abundance, of major phytoplankton groups, protozoans, and rotifers. Includes comments on seasonal fluctuations in abundance of certain forms.

Allin, A. E.
1929. Seining records and food of the intermediate stages of Lake Erie fishes. In: Preliminary report on the cooperative survey of Lake Erie--season of 1928. Bull. Buffalo Soc. Nat. Sci., Vol. 14, No. 3, pp. 188-194.
Record by number and species of fish taken in small number of hauls with Petersen and Helgoland trawls and with 50-foot seine, and analysis of stomach contents of fish taken by seine.

1929. Seining records and food of the intermediate stages of Lake Erie fishes. In: A preliminary report on the joint survey of Lake Erie. Suppl. 18th Ann. Rep., N. Y. Cons. Dept., pp. 95-106.
Report on same materials covered in paper issued by same author in same year under same title.

Burkholder, Paul R.
1929. Biological significance of the chemical analyses. In: Preliminary report on the cooperative survey of Lake Erie--season of 1928. Bull. Buffalo Soc. Nat. Sci., Vol. 14, No. 3, pp. 65-72.
General discussion of biological importance of various constituents of the water and description of Lake Erie as a tolerably hard-water lake, with moderate amounts of nitrogenous substances in solution, and free of injurious depletion of dissolved oxygen.

1929. Microplankton studies of Lake Erie. In: Preliminary report on the cooperative survey of Lake Erie--season of 1928. Bull. Buffalo Soc. Nat. Sci., Vol. 14, No. 3, pp. 73-93.
Study of the composition, vertical and horizontal distribution, and seasonal variation of the microplankton of eastern Lake Erie. Includes lists of phytoplankton forms, protozoans, and rotifers.

1929. Microplankton studies of Lake Erie. In: A preliminary report on the joint survey of Lake Erie. Suppl. 18th Ann. Rep., N. Y. Cons. Dept., pp. 60-66.

Report on same materials covered in paper issued by same author in same year under same title.

Eggleton, Frank E.

1936. The deep-water bottom fauna of lake Michigan. Pap. Mich. Acad. Sci., Arts, and Lett., Vol. 21 (1935), pp. 599-612.

Preliminary paper on bottom fauna samples collected with Petersen dredge from research vessel Fulmar in 1931 and 1932. Includes information on geographical and bathymetric distribution of the samples, list of major bottom forms, and statement of possible existence of concentration zone at about 40-50 meters.

1937. Productivity of the profundal benthic zone in Lake Michigan. Pap. Mich. Acad. Sci., Arts, and Lett., Vol. 22 (1936), pp. 593-611.

Continuation of 1936 study by same author. Pontoporeia dominated the bottom fauna (65 percent of total number) and that form together with Pisidium and Tubificidae made up 94 percent of the total. Data given also on vertical distribution and seasonal fluctuations in numbers of bottom forms.

Fish, Charles J.

1929. Preliminary report on the cooperative survey of Lake Erie--season of 1928. Bull. Buffalo Soc. Nat. Sci., Vol. 14, No. 3, 220 pp.

Report on studies of hydrography, bacteriology, chemistry (including chemistry of pollution), plankton, and ichthyology of Lake Erie east of line from New York-Pennsylvania boundary to Long Point (Ontario). In addition to introductory and concluding pages by Fish, includes nine articles by various authors on different phases of the survey.

1929. A preliminary report on the joint survey of Lake Erie. Suppl. 18th Ann. Rep., N. Y. Cons. Dept., pp. 39-106.

Condensation of report issued by same author in same year under similar title.

Fish, Marie Poland

1929. Contributions to the early life histories of Lake Erie fishes. In: Preliminary report on the cooperative survey of Lake Erie--season of 1928. Bull. Buffalo Soc. Nat. Sci., Vol. 14, No. 3, pp. 136-187.

Preliminary report on investigations published in full in 1932 paper by same author.

1929. Contributions to the early life histories of Lake Erie fishes. In: A preliminary report on the joint survey of Lake Erie. Suppl. 18th Ann. Rep., N. Y. Cons. Dept., pp. 76-95.

Preliminary report on investigations published in full in 1932 paper by same author; similar to other 1929 report under same title.

1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters. Bull. U. S. Bur. Fish. Vol. 47, pp. 293-398.

Profusely illustrated description of various stages of early development with notes on the occurrence of young and on breeding habits of the adults. Includes directions for preparation of specimens.

Hough, Jack L.

1952. Fathogram indications of bottom materials in Lake Michigan. Sedimentary petrology, Vol. 22, No. 3, pp. 162-172.

Fathograms obtained in Lake Michigan by commercial sonic sounding equipment showed characteristic traces for sand, till, and clay bottom. Multiple traces were correlated with specific clay strata.

Hough, Jack L.

1955. Lake Chippewa, a low stage of Lake Michigan indicated by bottom sediments. Bull. Geol. Soc. Am., Vol. 66, pp. 957-968.

From the nature of core samples from various depths it is concluded that in a period identified as post-Algonquin and pre-Nipissing the level of Lake Michigan was 350 feet below the present stage. This low-level "Lake Chippewa" drained northward through the Straits of Mackinac into a low-level Lake Huron, termed "Lake Stanley".

Parmenter, Richard

1929. Hydrography of Lake Erie. In: Preliminary report on the cooperative survey of Lake Erie--season of 1928. Bull. Buffalo Soc. Nat. Sci., Vol. 14, No. 3, pp. 25-50.

Report on physical limnology of eastern Lake Erie including data on vertical and horizontal distribution of temperature, on currents (both the "natural flow" and currents resulting from wind, pressure gradients, ...), and on transparency.

1929. Hydrography. In: A preliminary report on the joint survey of Lake Erie. Suppl. 18th Ann. Rep., N.Y. Cons. Dept., pp. 45-55.

Report on same materials covered in paper issued by same author in same year under similar title.

Pegrum, Reginald H.

1929. Topography of the Lake Erie basin. In: Preliminary report on the cooperative survey of Lake Erie--season of 1928. Bull. Buffalo Soc. Nat. Sci., Vol. 14, No. 3, pp. 17-24.

Description of the (Devonian) rocks underlying eastern Lake Erie, of the shore topography and the bottom deposits (principally mud and clay but with considerable stretches of sand, and some rock outcrop).

Williams, Roger C.

1929. Pollution studies in the light of the chemical analyses. In: Preliminary report on the cooperative survey of Lake Erie--season of 1928. Bull. Buffalo Soc. Nat. Sci., Vol.14, No. 3, pp. 60-64.

Record of chemical analyses of water of eastern Lake Erie for dissolved oxygen, various forms of nitrogen, pH, CO_2, and carbonates. No evidence of harmful pollution appeared at any station in the open lake.

1929. Chemical studies of Lake Erie. In: A preliminary report on the joint survey of Lake Erie. Suppl. 18th Ann. Rep., N. Y. Cons. Dept., pp. 58-60.

Report on same materials covered in paper issued by same author in same year under similar title.

Wilson, Charles B.

1929. The macroplankton of Lake Erie. In: Preliminary report on the cooperative survey of Lake Erie--season of 1928. Bull. Buffalo Soc. Nat. Sci., Vol. 14, No. 3, pp.94-135.

Brief comments on significance of plankton in fish production followed by data on horizontal and vertical distribution of macroplankton in eastern Lake Erie. Includes annotated systematic list of organisms.

1929. The macroplankton of Lake Erie. In: A preliminary report on the joint survey of Lake Erie. Suppl. 18th Ann. Rep., N. Y. Cons. Dept., pp. 67-76.

Report on same materials covered in paper issued by same author in same year under same title.

Zillig, Andrew M.

1929. Bacteriological studies of Lake Erie. In: Preliminary report on the cooperative survey of Lake Erie--season of 1928. Bull. Buffalo Soc. Nat. Sci., Vol. 14, No. 3, pp. 51-58.

Results of bacteriological examination of water at numerous stations in eastern Lake Erie, indicating that pollution was not a factor in the abundance of fish.

1929. Bacterial studies of Lake Erie. In: A preliminary report on the joint survey of Lake Erie. Suppl. 18th Ann. Rep., N. Y. Cons. Dept., pp. 56-58.

Report on same materials covered in paper issued by same author in same year under similar title.

PATENTS AND PATENT APPLICATIONS

Disclosure: VOLTAGE MEASURING APPARATUS
Number: 2,688,116
Date: Patented Aug. 31, 1954
Assignee: United States of America
Use: Measurement of intensity and direction of voltage gradients in fluid media, particularly natural waters; facilitates 3-dimensional plotting of electrostatic field patterns and field intensities.
Inventors: William L. Stahl and Vernon C. Applegate

Disclosure: METHOD AND APPARATUS FOR CONTROLLING AQUATIC ANIMALS
Number: Application Serial Number 341,054
Date: March 9, 1953 (Application approved by examiner; patent will issue January 18, 1957)
Use: Selective control of migratory fish and fish-like vertebrates in streams through the use of AC and DC fields of predetermined intensity.
Inventors: Vernon C. Applegate, Bernard R. Smith, and William L. Stahl

Disclosure: METHOD FOR CONTROLLING PETROMYZON MARINUS
Number: Application Serial Number 574,931
Date: March 29, 1956
Use: Control of sea lamprey populations by the chemical treatment of streams with 3-bromo-4-nitrophenol, a selectively toxic agent. Controlled applications permit destruction of all larval lampreys in a watershed without causing significant harm to other aquatic life.
Inventors: Vernon C. Applegate and John H. Howell

Disclosure: METHOD FOR CONTROLLING SEA LAMPREYS (PETROMYZON MARINUS)
Number: Application Serial Number 583,889
Date: May 9, 1956
Use: Control of lamprey populations by the chemical treatment of streams with O-ethyl-S-pentachlorophenyl thiolcarbonate, a selectively toxic agent. Controlled applications permit destruction of all larval lampreys in a watershed without causing significant harm to other aquatic life.
Inventors: Vernon C. Applegate and John H. Howell

Disclosure: METHOD OF CONTROLLING SEA LAMPREYS WITH HALOGEN NITROPHENOLS
Number: U.S. Dept. Int. Case No. FWS-313
Date: July 13, 1956
Use: Control of lamprey populations by the chemical treatment of streams with various halogen mononitrophenols. These selectively toxic agents destroy the larval stage of the sea lamprey without causing significant harm to other aquatic life.
Inventors: Vernon C. Applegate and John H. Howell

ROSTER OF BIOLOGISTS

Fishery research biologists employed as full-time staff members of Great Lakes Fishery Investigations 1950 or later, terms of employment, and stations (A, Ann Arbor; H, Hammond Bay; L, Ludington; M, Marquette; S, Sturgeon Bay)

Name	Years	Station
Anderson, Gaylord A.	1954-	M, L
Applegate, Vernon C.	1950-	A, H
Beil, Joseph	1950-	M
Braem, Robert A.	1952-	H, M
Brynildson, Clifford L.	1950-54	H
Cable, Louella E.	1950-	A
Carr, Ira A.	1956-	A
Durkin, Joseph T.	1954-	M
Elliott, Oliver R.	1950-54	H, M
Erkkila, Leo F.	1950-	M, A
Eschmeyer, Paul H.	1950-56	A
Gaylord, William E.	1950-	H, M, L
Glidden, Willis S.	1950-56	A
Gooden, Samuel K.	1956-	L
Hall, Albert E., Jr.	1950-55	H
Hile, Ralph	1933-	A
Howell, John H.	1953-	H
Joeris, Leonard S.	1950-	S, A
Johnson, James H.	1956-	A
Leach, W. James	1950-	H
Lennon, Robert E.	1950-52	A, H
Loeb, Howard A.	1950-53	H
McLain, Alberton L.	1950-	H, M
Marquette, Willman M.	1953-	M
Miller, Richard G.	1953-	M, L
Moffett, James W.	1950-	A
Moore, Harry H.	1954-	M
Parker, Phillip S.	1950-53	H
Piavis, George W.	1955-	H
Smith, Bernard R.	1950-	H, M
Smith, Stanford H.	1949-	A
Sullivan, Leo J.	1956-	L
Tetzloff, Clifford L.	1950-	M, A
Torblaa, Richard L.	1956-	L
5/ Van Oosten, John	1920-	A
Wells, LaRue	1953-	M, A

5/ Engaged in special research, administratively independent of Great Lakes Fishery Investigations after 1949.

Fishery research biologists employed part-time in support of graduate research

Name	Years	University
Allen, Kenneth M.	1953-	Michigan
Bodola, Anthony	1953-56	Ohio State
Knapp, Robert J.	1956-	Minnesota
Pycha, Richard L., Jr.	1952-56	Minnesota
Sawyer, Philip H.	1950-52	Michigan
Wigley, Roland L.	1950-52	Cornell

Fishery research biologists who collaborated in research but were not compensated

Name	Years	University
El-Zarka, Salah	1954-57	Michigan
Smith, Lloyd L., Jr.	1951-	Minnesota

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